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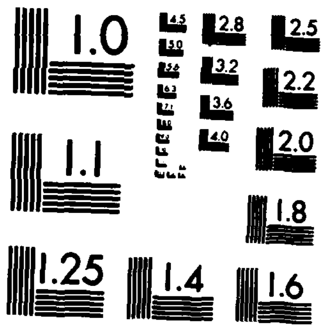
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AD-A146 958

COST MODEL FORMULATION FOR ESTIMATING
ARCHITECT - ENGINEER FEES AT
BASE-LEVEL CIVIL ENGINEERING

THESIS

James T. Ryburn
Captain, USAF

AFIT/GEM/LSM/84S-17

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BASE-LEVEL CIVIL ENGINEERING

THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Engineering Management

James T. Ryburn, RA, BArch
Captain, USAF

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Approved for public release; distribution unlimited

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James T. Ryburn

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Abstract

The purpose of this research was to statistically analyze a base-level data base of Architect-Engineer (A-E) contracts to demonstrate the possibility of cost model formulation to predict or estimate A-E fees. The models were based on the "cartooning" estimating technique for developing fee estimates based on the expected number of drawings required in the final A-E design. The data base was the A-E contracting activity of the 2750th Civil Engineering Squadron at Wright-Patterson AFB, Ohio, and included 44 contracts from a five year period. Analysis of variance was used to separate project characteristics which affected the per drawing cost. Utility Work, number of disciplines, community facilities, and total number of drawings affected the per drawing cost. Simple and multiple linear regression were used to derive cost models for predicting A-E fees on future projects. Four cost models were developed. Only one cost model using number of drawings was judged successful based on the statistical criteria. However the technique of cost model formulation for estimating A-E fees was demonstrated.

COST MODEL FORMULATION FOR ESTIMATING ARCHITECT - ENGINEER FEES AT BASE-LEVEL CIVIL ENGINEERING

I. Introduction

General Issue

Air Force Civil Engineering is responsible for the design and construction of all Air Force real property facilities worldwide and the maintenance and repair of all existing Air Force facilities. Architect and engineer (A-E) services are necessary for preparing plans and specifications for new construction, maintenance and repair, and alteration projects needed to meet Air Force Civil Engineering requirements.

Although a considerable portion of these A-E functions are accomplished by the civilian and military professional staffs employed by the Air Force, there are many projects which require the services of private A-E firms. Private A-E firms may be used for designing Air Force projects because of excessive workloads or limited technical capabilities of in-house professionals or when required by policy or regulation. For complex, specialized, or unusual projects, A-E services may be requested by the commands or directed by headquarters Air Force. (1:2-4)

For many reasons, the use of private A-E firms has been a growing trend within the Air Force through the late 1970's and early 1980's. In 1983, Air Force Civil Engineering activities spent over $45 million on A-E services from operations and maintenance (O & M) funds alone. Table I shows the growth of A-E services from 1981 through 1983.

TABLE I

O & M Expenditures for Construction and A-E Services (2)

	1981	1982	1983
Construction	$415M	$528M	$512M
A-E Fees	$36.0M	$38.5M	$45.4M

A-E firms are selected for Air Force work through a five part procedure known as the "traditional selection method". This procedure has evolved from a long series of statutes beginning in 1939 when congress authorized the use of outside A-E services. This five part process consists of:

1. Identifying the need for services and notification of the A-E community.

2. Reviewing the qualifications of interested A-E firms.

3. Ranking A-E firms based on technical and

professional competence, proximity and availability, and volume of DOD work previously awarded.

4. Negotiating with the firm selected as most qualified.

5. And, if negotiations are not successful, continued negotiating with each successively ranked firm until a successful conclusion is reached. (3:3)

Negotiating A-E contracts and the traditional selection method are codified into public law by the "Brook's Bill", P.L. 92-582, which was enacted in 1972. The Brook's Bill requires that agency heads negotiate a "fair and reasonable" fee for A-E compensation, and negotiate with only one firm at a time. When negotiations with the first "most qualified" firm fail to reach a fair and reasonable price, negotiations with that firm are terminated and may not reopen. This sequential negotiation procedure and the concept of fair and reasonable fees prevents the contracting officer from comparing or shopping for prices and awarding the contract with the lowest cost to the government. Therefore, unlike nearly all other government procurements, A-E firms do not directly compete for government contracts on the basis of price.

The Federal Acquisition Regulation (FAR), and DOD supplement thereto, requires an independent cost estimate for A-E services, prepared by the Government, on the basis of a detailed analysis of the required work as though the

Government were submitting the proposal. This estimate is provided to the contracting officer and used as the measure of "reasonableness" of the fee offered by the A-E. It is essential then, that the Government estimate accurately reflects a "fair and reasonable" compensation for the A-E services desired.

Accuracy of this fee estimate is complicated by the fact that A-E services are not typical supplies or services where the desired end product or result is known in advance. The A-E service being purchased is an "ultimate design concept which evolves during performance of the service " (4:42). The government is buying professional skill and creative talent. Professional skill and creative talent are abstract concepts and not easily quantified (5:53).

In order to quantify design services, the government estimator is required to break down his estimate into estimates of time required for individual design tasks and then apply estimated hourly rates. Since the Air Force provides no definitive guidance, Civil Engineering estimators rely on individual experience to calculate design hours to reach A-E fee estimates. Captains Moss, Meister, and Ruschman calculated in their 1978 Air Force Institute of Technology thesis that Air Force Civil Engineers could only achieve plus or minus 30 percent accuracy on estimates of their own in-house design hours (6). Other research by Col. J.D. Pearman USAF, and Lt. E. Herndon, CEC, USN has pointed

out deficiencies in current methods of determining fair and reasonable A-E fees. (3) (7)

New methods for predicting design hours and A-E fees have been proposed by Moss, Meister, and Ruschman and by Herndon. Both methods use statistical analysis of existing data, available to the Government estimator, to formulate cost or design hour prediction models.

Since the work of Moss, Meister and Ruschman (1978) and Herndon (1981), Air Force Civil Engineering activies have acquired data processing capabilities for its base-level Civil Engineers. The availability of data processing equipment and a continuing historical data base at base level suggests that the new analysis techniques might be applied to estimating A-E fees.

Problem Statement

The pricing objective for negotiated A-E fees is not the lowest possible price, but a price that is fair and reasonable. This is usually defined as a "price that will give a competent contractor [A-E] reasonable remuneration for the application of his technical, financial, and production resources..." (8:1-2). Unfortunately the definition of "fair and reasonable", like the A-E firm's service, is difficult to quantify. "Fair and reasonable" is usually based on a comparison of fees to similar fees under current market conditions.

This implies that a fair and reasonable fee could be determined by comparison to fees for similar projects under similar market conditions. This is the basis for cost model formulation from an existing project data base.

The tangible output of an A-E firm's services, and a part of the civil engineer's available data base, are the drawings and specifications. This output of the A-E contract is easily quantified. One manual method of estimating A-E fees has been to estimate the number of drawings by discipline, and apply an estimated per drawing cost. This is the so-called "cartooning" estimating method.

The general hypothesis of this research is:

A relationship exists between the number of drawings by discipline produced by an A-E contract and the final negotiated A-E fee.

If this hypothesis is true, then, by use of computerized statistical techniques, these relationships can be derived from the historical data available from past A-E projects.

Background and Literature Review

Types of A-E Services. The Air Force awards A-E contracts for the following primary types of services:

1. Title I:

a. field surveys and investigations required to obtain design data.

b. preparing designs, plans, drawings, estimates and specifications as required to execute a construction project.

2. Title II:

a. supervising and inspecting construction.

b. preparing as-built drawings (1:2-4)

The scope of an A-E contract can involve any or all of the following work:

1. Investigations to determine feasibility of proposed projects.

2. Other preliminary investigations and analyses.

3. Collecting design data, such as topographic surveys, subsurface and soil investigations, traffic census, origin and destination studies.

4. Investigating existing conditions preliminary to alterations.

5. Preparing construction contract plans, specifications, and final cost estimates.

6. Assisting with interpretation of plans and specifications during construction.

7. Checking shop drawings submitted by the construction contractor.

8. Resident engineering service during construction.

9. Inspecting completed construction, supervising performance tests and related items to determine conformance with plans and specifications.

10. Preparing "as-built" drawings for record.

11. Consulting and other related technical and professional services. (7:21)

The majority of base level A-E contracts are for design services, Title I b. services. (7)

Six Percent Fee Limitation. Since 1939, most Government construction agencies, including the Air Force, have been required by law (10 U.S.C. 7212) to limit the fee payable to an architect or engineer to six percent of the Government's estimated construction cost. The Federal agencies have interpreted the statutory fee limitation as applying only to that part of the fee which covers the production and delivery of "designs, plans, drawings and specifications." These are so-called Title I b. services. The limitation does not apply to fees for field investigation, surveys, topographical work, soil borings, inspection of construction, master planning, and other services not involving production and delivery of designs, plans, drawings, and specifications. (9:31)

Authority for Contracting A-E Services. The legislative authority used by the Air Force to procure A-E services is 5 U.S.C. 3109 implemented through each Defense Appropriation

Act (10:5). The Secretary of the Air Force delegates this authority for procurement of A-E services with fees below $250,000 to commanders. (11)

Authority for negotiating A-E contracts is provided by the Federal Acquisition Regulation paragraphs 15.204 and 36.606, "Negotiations". The statutory authority is derived from Public Law 92-582 which states:

> Congress hereby declares it to be the policy of the Federal Government to publicly announce all requirements for architectural and engineering services, and to negotiate contracts for architectural and engineering services on the basis of demonstrated competence and qualification for the type of professional services required at fair and reasonable prices. [9:15]

<u>The Traditional Selection Method</u>. Public Law 92-582, better known as the "Brook's Bill" - after the Texas Congressman who sponsored it - was enacted in 1972. (9:14) The Brook's Bill is reproduced in Appendix A. The Air Force implements the Brook's Bill through AFR 88-31 which states:

> A-E selections are based solely on comparative evaluations of the professional and technical qualifications considered essential for satisfactory performance of the work and services required. Do not use competitive bidding or comparable procedures [10:2]

The Brook's Bill codifies the so-called five part "traditional selection method".

<u>Synopsis</u>. Step one of the traditional selection method is identifying the need for services and notification

of the A-E community. AFR 88-31 implements this requirement of the Brook's Bill by requiring that any A-E requirements that are expected to exceed $10,000 are synopsized in the Commerce Business Daily. Contracts below $10,000 are advertised by display of a synopsis at the base contracting office.

The synopsis includes a brief statement concerning the location, scope of services required, the significant evaluation factors and their relative priority, the range of the Government's estimated construction cost, type of contract proposed, the estimated start and completion dates, and the deadline for responding to the notice. Statements are included concerning any specialized qualifications, security classifications, and any limitations on eligibility. (10:7-8)

Preselection and Selection. Steps two and three of the traditional selection method include reviewing the qualifications of A-E firms, ranking the firms, and selecting the most qualified firm. A-E firms interested in consideration for contracts must periodically submit a Standard Form 254 to the appropriate Civil Engineering office. Standard Form 254 is the "U.S. Government Architect-Engineer and Related Services Questionaire". The form classifies A-E firms by location, specialized experience, professional capabilities, capacity to perform work, and performance on previous jobs. The 254 is a

general resume of the firm's experience. It is kept on file at the Civil Engineering office. (12:4-6)

The Standard Form 255, "Architect-Engineer and Related Services Questionaire for Specific Project", is submitted by a firm in response to advertisement of a specific project. It may be requested by the synopsis. The Standard Form 255 supplements the information in the Form 254 with information relevant to a specific project. (10:7)

Selection is based on information contained in the Standard Form 254 and Form 255 (if required). For all contracts where estimated fees exceed $10,000, two formally constituted boards are convened (12:5), a Preselection Board and Selection Board. Both boards are composed of three or more members of the civil engineer's staff "appointed on the basis of technical experience and maturity of judgement" (10:8). Members are appointed by special military orders.

The preselection board develops a listing of the best qualified firms from among the applicants. (12:5) Generally, all qualified firms with current Forms 254 on file are considered whether or not they respond to the advertisement (10:8). The preselection list generally contains eight to 15 firms, but six are required (12:5). Firms are listed based on a comparative evaluation of the technical and professional qualifications required and the capacity of the firm to perform the work (10:9).

The final selection board considers the preselection

results and selects a "short list" or "final slate" of firms from the preselection list. This list contains at least three firms with the top listed firm judged most qualified. These firms are interviewed by the board. This interview is a technical discussion only. Fees may not be discussed and the Government may not be obligated (10:9). Following these discussions, the board finally ranks the firms and provides its recommendations to the contracting officer. For contracts with fees estimated below $10,000, only one board is convened. For contracts below $2500 in fees, a formal selection board is not required. The civil engineer prepares a priority listing of A-E firms for the contracting officer.

Negotiation and Award. Step four of the traditional selection method is negotiating with the top ranked firm. Before negotiation can begin, an independent Government estimate of the cost of the A-E services and a well-defined Statement of Work must be prepared by the civil engineer and furnished to the contracting officer. The Federal Acquisition Regulation requires the estimate to

> ..... be prepared on the basis of a detailed analysis of the required work as though the Government were submitting a proposal. [13:36.605]

The selected A-E is notified and a detailed proposal is requested. The Government's estimate and the A-E firm's detailed proposal become the basis for negotiation.

Under the detailed analysis procedure, the proposal and the Government estimate are each broken down into manhour requirements and disciplines - architectural, structural, mechanical, electrical, draftsmen, surveyors - for each phase and type of service required; Title Ia., Title Ib., and Title II. Hourly rates are applied to the estimated manhours. Allowances are then made for overhead and profit to arrive at a total estimated fee (9:32). Appendix B illustrates a typical estimating sheet for the Government's detailed breakdown.

During negotiation, the civil engineer acts as technical advisor to the contracting officer. The contracting officer is the official responsible for the negotiation and award. (10:2)

The Government's estimate is not divulged to the contractor during negotiation (13:36.605). If significant difference exists between the Government's estimate and the A-E's proposal, review of those items which are out of line is made to assure there is no misunderstanding as to the scope of the service desired. Figures for individual items from the Government's estimate may be disclosed to the extent necessary to arrive at a fair and reasonable price, but under no circumstances is the Government's total estimate disclosed.

If a negotiated price cannot be reached with the selected A-E firm then negotiations are terminated and the

process begins again with the next ranked A-E firm. The next ranked firm is not given access to any information concerning price or technical information submitted by the previous firm (7:35). When a successful negotiation is concluded a contract can be awarded.

Contract Types. A-E services are usually purchased on the basis of a fixed, lump-sum fee. The fee is the negotiated price based on the A-E firm's hourly direct costs, overhead, and profit. The A-E's fee is different from the concept of fee as used in cost-plus-fee contracts. The A-E's fee is a lump-sum amount. (4:42)

Cost-plus-fixed-fee contracts are only used for A-E services if the nature of the project does not allow a definitive Statement of Work. For a cost-plus-fixed-fee contract expected to exceed $25,000, the specific approval of the Assistant Secretary of Defense for Manpower, Installations, and Logistics is required. (10:2)

In 1979 the Air Force received permission to award open-ended A-E contracts. The open-ended contract allows greater flexibility for civil engineers by allowing the same A-E firm to design several projects. Open-ended A-E contract refers to a special category of indefinite quantity - indefinite delivery contract for an A-E firm's services.

Under an open-ended contract, an A-E firm is guaranteed a minimum of $5,000 in fees, and the ceiling for total fees is $250,000. During the period of the open-ended

contract, the civil engineer may submit projects for design to the contracting officer. The contracting officer then negotiates separate delivery orders for each project. After the first project, fees for a subsequent project cannot exceed $40,000. Open-ended contracts may not exceed one year, but may cross fiscal years. (14)

Open-ended contracts must meet all other requirements of A-E contracts over $10,000 to include synopsis, formal preselection, and formal selection. But for an open-ended contract this lengthy process is only executed once for the initial selection.

Estimating A-E Fees. The requirement for Government's detailed analysis of estimated A-E fees is established by the Federal Acquisition Regulation which states:

> An independent Government estimate of the cost of architect-engineer services shall be prepared and furnished to the contracting officer before commencing negotiations for each proposed contract or contract modification expected to exceed $25,000. The estimate shall be prepared on the basis of a detailed analysis of the required work as though the Government were submitting a proposal. [13:36.605]

The FAR is supplemented by the DOD FAR supplement which requires an estimate for every contract expected to exceed $10,000 in fees. (15:36.605)

Under the Brook's Act, the criteria for a fair and reasonable fee is the government estimate. After mutual understanding has been reached on the scope of work during negotiations, differences in the A-E firm's prices and the

government estimate are discussed and resolved. A contract may not be awarded for more than the Government estimate. If, during discussions, the Government's estimate is found in error or is unreasonable, it is modified as appropriate. (7:53-54)

<u>Methods of Estimating</u>. There are many techniques used in the industry for estimating design fees. Several of the methods used in Government and commercial practice are described below.

The simplest method for calculating fees is the "percentage of estimated construction cost" method. Until recent years, an A-E was paid a simple mutually agreed upon percentage for his work. Graphs or schedules depicting suggested fees were prepared and distributed to their membership by professional societies, such as the American Institute of Architects and the American Society of Civil Engineers. Figure 1 shows a typical graph presented by the American Institute of Architects in 1959 (16). The graph shows four facility types reflecting relative complexity of the design effort. Also as construction costs increase, the percentage declines. These fee ranges were developed from experience and reflected "average" fees (3:22). Most Government agencies must use the detailed analysis method but the percentage of estimated construction cost method can be used as a guideline in determining cost and often is used because of the six percent statutory limit.

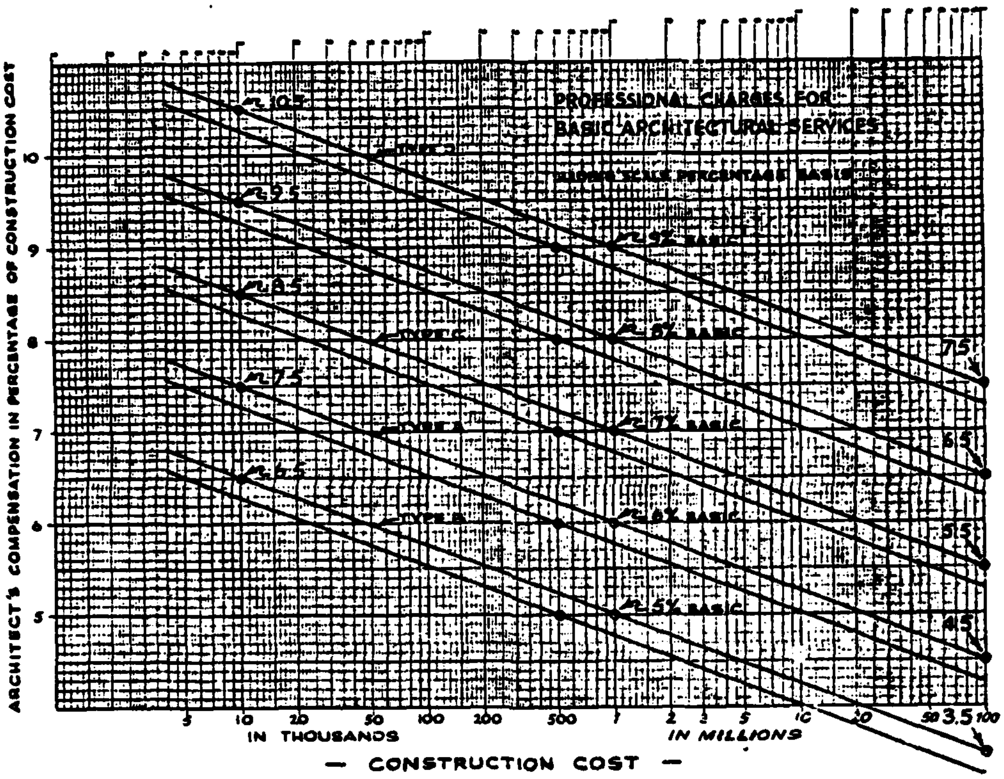

Figure 1. A-E Fee Chart. (Reprinted from Architectural Practice. 1959). (16)

The percentage method is widely used in industry to develop early gross-order-of-magnitude estimates. Table II shows estimated A-E fees from the 1984 Mean's <u>Building Construction Cost Data</u>.(17)

TABLE II

A-E Fees as a Percentage of Construction Cost. Reprinted from <u>Building Construction Cost Data</u>. 1984. (17)

Building Type	Total Project Size in Thousands of Dollars						
	100	250	500	1,000	2,500	5,000	10,000
Factories, garages, warehouses repetitive housing	9.0%	8.0%	7.0%	6.2%	5.6%	5.3%	4.9%
Apartments, banks, schools, libraries, offices, municipal buildings	11.7	10.8	8.5	7.3	6.7	6.4	6.0
Churches, hospitals, homes, laboratories, museums, research	14.0	12.8	11.9	10.9	9.5	8.5	7.8
Memorials, monumental work, decorative furnishings	—	16.0	14.5	13.1	11.3	10.0	9.0

In the "phase and compensation" method, a given fee is assumed, and the fee is broken down into a payment schedule according to each project phase. For example, 20 percent of the fee may be designated for the concept phase; 30 percent for preliminary design; 40 percent for working drawings; and 10 percent for bidding or negotiating. The amount of money in each phase is then divided by the hourly rate normally charged, and a resulting number of manhours for each phase is determined. The accuracy of this method relies on the experience and ability of the estimator to determine the amount of effort which is used to determine the design fee. (6:8)

The "detailed analysis" method is a technique of determining the number of engineering design manhours based

on a detailed analysis of the elements required broken down by specific discipline (7:55). All direct costs are itemized in detail. These include the hourly rate or salaries of the architects, engineers or technicians to be used on the job, the transportation expenses required in connection with performance of the contract, and miscellaneous expenses such as telephone, printing, outside consultants, models, laboratory tests, and similar services required by the contract. Certain costs are not recognized by the Government and are called "unallowable" costs. Commissions or bonuses in connection with obtaining a Government contract, contingency reserves, entertainment, and interest are examples of costs not allowed.

After direct costs are summed, the Government will add (a) direct labor overhead and (b) general and administrative expenses. Direct labor overhead includes (a) taxes, (b) pension, health accident and life insurance plans, and (c) vacation, holiday and severance pay and sick leave. Direct overhead is usually expressed as a fixed percentage of direct costs.

General and Administrative expenses are other costs of doing business which which are for the general management and supervision of the business. This includes (a) over-all supervision, (b) accounting and clerical work, and (c) supplies, equipment depreciation, rental, and utilities.

After direct and indirect costs are summed a percentage rate is applied for profit. Some Government

agencies fix the percentage allowed for profit. (9:34-36)

The "cartooning" method is a technique based on the estimated number of drawings which may be required, the amount of information or detail which should be contained on each sheet, and some knowledge of how many manhours it will take to complete each sheet. It is called "cartooning" because the estimator frequently makes small sketches of the sheets to visualize the number of final drawings required. To use this technique, an estimator must be experienced in all of the engineering disciplines involved in a design or have access to experienced designers who can provide the necessary information. In addition, the estimator must have established a data base on man-hours per sheet of drawings. (7:56-57) (18:I.26 - I.29)

<u>The Air Force Method</u>. In practice, the Air Force uses a combination of the cartooning and detailed breakdown methods. The estimating form shown in Appendix B is used by Tactical Air Command. It shows columns for number of drawings and number of manhours. The other commands have developed similar forms for developing the Government's estimate. Costs are separately identified for Title Ia., Title Ib., and Title II services to monitor the six percent statutory limitation.

Cost Model Formulation

Cost formulation models for alternative methods of contract proposal and evaluation have been advocated by several authors. The government has the advantage of many well documented contracts for similar A-E services, which, if organized into an acceptable data base, could provide the basis for model formulation (5). Two attempts at cost model formulation for predicting A-E design hours or cost are documented below.

The Research of Moss, Meister, and Ruschman. Moss, Meister, and Ruschman analyzed the design variables which affect the time required to design a project in order to develop a model for estimating required design manhours. Using survey data from 45 design sections located in the CONUS, multiple linear regression was used to statistically analyze the effect independent design variables (cost of project, complexity, number of disciplines, experience of the engineer, type of work, type of funds, modularity and repetition, and drafting work by engineer) had on the dependent variable (design manhours). Although their method was developed for predicting in-house design hours, they advocated its use to predict A-E hours also.

They found that cost of the project, complexity of the project, and experience of the engineer most affected

the design time required for the project. The relationship was too weak to produce an accurate model using the composite data, however they found a strong relationship existed in the data from individual bases. (6)

<u>The Research of Herndon</u>. Herndon attempted to define cost estimation as a decision process using analytical computations, statistical techniques, and regression cost models, using a FORTRAN program. He collected data from the memorandum of negotiation on 300 A-E contracts from the Navy's Western Division, Facilities Engineering Command. He then developed several cost models for predicting A-E fees. He found that these techniques produced accurate fee estimates. For model validation he chose three A-E contracts not in the model and accurately predicted their final negotiated cost. (7)

Herndon advocated use of the cartooning method of estimating and calculated the cost per drawing based on the predicted total number of drawings from the negotiation memorandum, not the actual number of finished drawings. (7)

Research Objectives

The objectives of this research are:

1. Analyze an existing data base of completed A-E projects to determine if there is a relationship between the actual number of finished drawings and negotiated fee.

2. Develop a model based on the cost per drawing relationship to pre`ict or estimate "fair and reasonable" A-E fees.

3. Demonstrate the usefulness and accuracy of the model for estimating A-E fees at base-level Air Force Civil Engineering.

Research Questions

In order to meet the research objectives, the following research questions must be answered.

1. Can a relationship between A-E fee and number of drawings be established from a base-level data base?

2. Is the relationship powerful and accurate enough to predict or estimate A-E fees for future projects?

Scope and Limitations

The Air Force has little involvement with the selection of A-E firms or the negotiation of A-E contracts funded through the Military Construction Program (MCP). This responsibility is assigned by law to the Army Corps of Engineers and the Navy Facilities Engineering Command (12:1). These agencies function as the design and construction agents for the Air Force for almost all MCP projects. Since the Air Force has limited involvement in the MCP process, the research deals primarily with the estimation of A-E fees for design of family housing,

operations and maintenance and non-appropriated fund projects. The responsibilities for estimating these A-E contracts is concentrated at base level and in some cases with the Air Force Regional Civil Engineer Office. (12:2)

Two other important factors accepted as given are:

1. continuation of the requirements of the Brook's Bill, and
2. continuation of the statutory six percent limitation on Title Ib services.

There has been much criticism of the Brook's Bill with the traditional selection method and the six percent limitation. A full review is outside the scope of this research.

Also, this research was limited to only those A-E services which led to construction. Although A-E firms provided other services such as studies and research, no attempt was made to analyze those fees for those services.

II. Methodology

This chapter is divided into two sections which describe the methodology used in this research. The first section describes the data base, sample, variables and data acquisition procedures. The second section describes the statistical techniques used in analyzing the project data collected.

Developing the Data Base

Population and Sample. The population for this research was all base-level A-E contracts which led to design of construction projects for the United States Air Force. For this effort, the contract data from the 2750th Civil Engineering Squadron (CES), Wright-Patterson AFB was used as a case example. The case sample was selected to demonstrate a method for base level estimators. While the numerical findings of the research would only apply to the A-E contracts of the 2750th CES, the effort of this research was intended to validate an estimating method. The data collection was limited to a single base because the time and effort required to gather the data made any kind of multi-base survey impractical and would introduce other variables related to geographic factors.

The sample included forty-four A-E designed projects

which were all the A-E projects on record which were managed by the 2750th CES at Wright-Patterson. Total A-E fees for those projects exceeded $900,000.

Identification and Definition of Variables. Many variables have been considered to have a significant effect on the A-E fee for a particular project. For this research, a combination of the variables identified as significant by Moss, Meister, and Ruschman and Herndon were selected to support the research objectives. Unlike previous efforts, this author attempted to avoid intangible or subjective measures and attempted to isolate those variables which could support the research objective of relating A-E fees to actual A-E project outputs. A list of variables considered but not used is shown in Appendix C. These variables were eliminated based on their availability from the data base or the author's experience in estimating A-E fees.

Dependent Variable. The actual final billing of the A-E fee was selected as the dependent variable. This variable was defined as the total dollars received by the A-E firm in return for services of each contract (or delivery order on open-ended contracts) inflated to constant 1984 dollars.

Independent Variables. Eleven descriptive factors for each contract were included in the data base. These factors were either measures of actual output or descriptors of the type of work for determining trends or differences

among different types of design work. The independent variables selected were:

<u>Date</u>. The year of execution of the design contract was selected as a descriptor to code dollar amounts for inflation adjustments. The date itself was not used as a variable.

<u>Work Code</u>. Work code is a nominal variable that identifies the type of work in the project as:

1 - New Construction

2 - Maintenance and Repair

3 - Alteration, Modification, Expansions

4 - Equipment Installations

5 - Retrofit

The definition of these variables was from standard Air Force Civil Engineering terminology.

<u>Category Code</u>. The type of facility under design was coded as follows:

0 - Family Housing

1 - Operations and Training

2 - Maintenance and Production

3 - Research, Development, and Testing

4 - Supply and Warehouse

5 - Medical

6 - Administrative

7 - Community

8 - Utilities

9 - Ground Structures

Estimated Construction Cost. The Government's estimated construction cost at the time of execution of the A-E contract was recorded as an independent variable. This estimate was selected since it would be the figure available to the estimator of A-E fees prior to the A-E contract.

Number of Drawings. This is the actual count of drawing sheets by discipline produced by the A-E contractor. The discipline was determined by the standard code on the "Index to Drawings" on the cover sheet to most projects. The codes were:

A - Architectural

C - Civil

S - Structural

E - Electrical

M or H - Heating, Ventilation, and Air Conditioning

M or P - Plumbing

FP - Fire Protection

L - Landscape

When the drawings were not coded or indexed, the experience of the author was used to determine the discipline for each sheet. When both heating, ventilation, and air conditioning and plumbing sheets were coded "M", the experience of the author was used to separate the sheets by discipline.

Data were collected for each of the eight discipline categories for each project. When no sheets were produced for a particular discipline, it was recorded as zero for that project.

Data Collection. The data for these variables were collected from the contract files of the 2750th Civil Engineering Squadron at Wright-Patterson AFB, Ohio. The author reviewed each contract file and extracted the data using the form shown in Appendix D.

Variable definitions were modified during the collection of data to correspond to the format and availability of the preidentified variables. The following descriptions outline the final form and definition of the data collected.

A-E Fee. When possible, the A-E fee was taken from the final certified invoice in the A-E contract file. If the invoice was not in the file, the fee was taken from the total contract cost, as modified, shown on the final contract or modification form. The fees were recorded rounded to the nearest dollar. In many cases, the total fee was not divided into Title Ia and Title Ib amounts. In order to make the data consistent, the fee was recorded as the sum of Title Ia and Title Ib services if two figures were given.

Date. The date was recorded as the date on the original contract or on each delivery order of an open-ended contract. The date was recorded as the two digit year, such as 80 for 1980.

Work Code. The work code was recorded as originally defined in the variable definitions. Many projects were combined maintenance and repair and alteration projects. In

those cases, the experience of the author was used to determined the prevalent work type. Several cases described as maintenance and repair were coded as equipment installations by the author when the prevalent work was replacement of equipment units (such as air conditioners, transformers, etc.) and the work was primarily design of the new equipment interface.

Category Code. The category code was recorded as originally defined in the variable definitions. However, in many cases, the building type was not relevant to the project work and there were several functions within the building. Some project description within the contract file did not mention the building type but only referred to the building number. So in some cases, the recorded building type was the best guess of the author based on available information. On multi-facility projects the author attempted to record the primary facility type.

Estimated Construction Cost. Estimated construction cost was taken from the original A-E statement of work prepared by Civil Engineering. In those cases where the statement of work was not available or it did not contain the necessary information, the estimated construction cost was taken as the funded cost from the DD form 1391 dated prior to the award of the A-E contract.

Number of Drawings. The number of drawings was recorded for each of the eight disciplines as outlined in the variable definitions. When possible, the drawings were

physically counted as taken from the final A-E submittal. These drawings were filed with the 2750th CES as open or closed projects. Open projects were filed in the Engineering Design Section. Closed projects were filed with record drawings in the storage vault. In some cases, where drawings could not be located, the count was taken from the A-E prepared specifications reference to "drawings" in the General Conditions. No landscape drawings were in the data base and that category was eliminated from the data.

Data Transformations. Several new variables were created from the data base. Descriptions of these variables are outlined below.

Total Drawings. The total number of drawings for each case was calculated as the sum of architectural, structural, civil, electrical, HVAC, plumbing and fire protection drawings. This sum was used to calculate the total 1984 dollars per drawing for each case.

Percentage of Estimated Construction Cost. The A-E fee was divided by the estimated construction cost to yield a fee percentage for each case. This fee percentage does not relate to the actual percentage rate at the time of negotiation because the variable fee is the final, as modified, total and not the originally negotiated fee. This was a design flaw in the data collection. However, this figure is useful for comparison with prediction models.

Number of Mechanical Drawings. The number of mechanical drawings was calculated as the sum of heating, ventilating, and air conditioning (HVAC), plumbing, and fire protection drawings. The fire protection drawings consisted of sprinkler and extinguishing system designs. These are drawings requiring the efforts of mechanical engineers.

Structural/Civil Drawings. The sum of structural and civil drawings was calculated to total the drawings requiring the efforts of civil engineers.

Number of Disciplines. The number of disciplines was calculated as the sum of one for each appearance of architectural, structural/civil, mechanical, or electrical drawings for each case. For example, a project with two architectural sheets and three mechanical sheets would have two disciplines.

Lead Discipline. The lead discipline was calculated as the discipline which produced the most drawings in the design.

The lead disciplines were coded as follows:

1 - Architectural

2 - Structural/Civil

3 - Mechanical

4 - Electrical

In case of ties, the lead was recorded in the following priority:

1 - Electrical

2 - Mechanical

3 - Structural/Civil

4 - Architectural

<u>Indexing for Inflation</u>. For the statistical tests, all dollar amounts were converted to constant 1984 dollars using index numbers. Index numbers are percentages indicating the change in values, quantity, or prices of a commodity or service over time (19:7). In this case, the estimated construction cost and A-E fees were recorded from a four year period. To realistically compare these projects, they had to be converted to a base year price to eliminate inflation as a source of variation. The index numbers chosen were the "Cost Growth Factors" published in the "Annual Construction Pricing Guide" for the fiscal years 1985 through 1989, Military Construction Program (20:6). The index numbers for July of each year were:

1980 - .693

1981 - .770

1982 - .836

1983 - .890

1984 - .935

These were converted to constant 1984 dollars by converting each index to its ratio with the 1984 index. This yielded new index numbers of:

1984 - 1.00

1983 - 1.05

1982 - 1.12

1981 - 1.21

1980 - 1.35

Each dollar figure from each case was multiplied by its appropriate index to give 1984 base year dollars.

Statistical Tests

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS), an integrated package of computer programs resident to the Aeronautical System Division's CDC Cyber computer at Wright-Patterson AFB, Ohio. The SPSS programs used are shown in Appendix E.

Discriptive Analyses. Descriptive procedures from SPSS were used to describe the nature of the data base. Two descriptive procedures were used; FREQUENCIES and CONDESCRIPTIVES. FREQUENCIES is a descriptive method which displays the data in histogram form. The CONDESCRIPTIVE procedure calculates the mean, standard deviation, and other numbers which describe the shape of the data distribution (21:29-36).

Frequencies. The FREQUENCIES procedures were used to generate histograms of estimated construction cost and A-E fees. Since these are interval data, the data had to be grouped into categories. Estimated construction cost was

classified as follows:

1 - $0 to $50K

2 - $50.1K to $100K

3 - $100.1K to $150K

4 - $150.1K to $200K

5 - $200.1K to $250K

6 - $250.1K to $300K

7 - $300.1K to $350K

8 - $350.1K to $400K

9 - $400.1K to $450K

10 - $450.1K to $500K

11 - $500.1K to $550K

12 - OVER $550K

A-E fees were classified as follows:

1 - $0 to $5000

2 - $5001 to $10,000

3 - $10,001 to $15,000

4 - $15,001 to $20,000

5 - $20,001 to $25,000

6 - $25,001 to $30,000

7 - $30,000 to $35,000

8 - $35,001 to $40,000

9 - OVER $40,000

Histograms were also generated to illustrate distributions of ordinal data. Histograms were output for year of project, work class, category codes and lead discipline.

Condescriptives. Condescriptives were prepared for fee as a percentage of estimated construction cost, fee dollars per drawing, total drawings per project, number of disciplines, A-E fee in 1984 dollars and estimated construction cost in 1984 dollars.

Inferential Analyses. Two inferential procedures from SPSS were used to estimate parameters of data groups based on the point estimates generated by the descriptive procedures. The ONE-WAY Analysis of Variance (ANOVA) procedure was used to determine whether any subgroups of the data base were substantially different from other groups in the data base. Both SCATTERGRAM and REGRESSION subroutines were used to describe any linear relationship between independent variables and the dependent variable, A-E fee.

ANOVA. ANOVA is a parametric statistical technique used to determine comparability between two or more population means (21). In this research, the SPSS ONE-WAY procedure was used to test whether any subgroups of the data base varied significantly from the rest of the data base for two variables: dollars per drawing and fee as a percentage of construction cost. The Student-Neuman-Keuls (SNK) procedure was used to separate any subgroups which were significantly different. The data base subgroups were:

1 - The data grouped by work class

2 - The data grouped by category code

3 - The data grouped by number of disciplines

4 - The data grouped by lead discipline

If subgroups of the population were significantly different, dummy variables were created to introduce the nominal categories into the regression analyses.

Regression Analyses. Regression analysis is a statistical technique used to describe whether a linear relationship exists between a dependent variable and independent variables for a set of data points. Multiple linear regression (MLR) takes into account the effect of more than one independent variable on the dependent variable. By using MLR, the relationship between A-E fees as dependent variable and number of drawings as the independent variables may be established. If a linear relationship exists, a model may be obtained which would predict or estimate A-E fees based on an estimated number of drawings. (21)

The MLR model equation will be in the form:

$$Y=B0+B1X1+B2X2+B3X3+B4X4$$

where:

Y = A-E fee

X1 = number of architectural drawings

X2 = number of structural/civil drawings

X3 = number of mechanical drawings

X4 = number of electrical drawings

MLR analysis was conducted for the data base to develop a model equation.

B1 through B4 represent a dollar per drawing

multiplier for each design discipline. BO represents a constant dollar figure for additional amounts not explained in the number of drawings.

Criteria for Statistical Tests. The results of ANOVA were examined at the 80 percent confidence level. All ANOVA tests began with the assumption that all groups were homogenous. If any ANOVA yielded an F statistic of less than .2, the assumption was rejected. The data was then examined to detect any subgroups within the group. The SNK test has a predetermined confidence level of 95 percent.

The results of regression were measured against the computed coefficient of determination. Any model with an R-squared value which exceeded .8 was considered successful. Variables in the equation were examined at the 95 percent significance level.

III. Findings and Analysis

Data Base Description

The mean A-E fee for the 44 projects at Wright-Patterson (in 1984 dollars) was $23,342, with a smallest fee of $3682 and a largest fee of $86,294. Figure 2 is a histogram of A-E fee distribution converted to 1984 dollars. Of the 44 projects, 34 fell in the range of $5000 to $35,000.

Estimated construction cost was distributed as shown in Figure 3. 35 of the 44 projects fell between $50,000 and $400,000. The median, in number of projects, fell in the $150,000 to $200,000 range. The actual computed mean in 1984 dollars was $298,741. In two cases, there was no recorded estimated construction cost. These were coded as MISSING VALUES for SPSS calculations.

The date of the projects was recorded as shown in Table III. These dates were used to code the dollar amounts for each case for multiplication by the appropriate index number. The work codes for the projects were recorded as shown in Table IV.

```
   I
1. *********** (      2)
   I  $0 TO $5000
   I
2. *************************************************** (     10)
   I  $5000 TO $10,000
   I
3. ************************** (      5)
   I  $10,000 TO $15,000
   I
4. ***************************************** (      8)
   I  $15,000 TO $20,000
   I
5. *********** (      2)
   I  $20,000 TO $25,000
   I
6. ************************** (      5)
   I  $25,000 TO $30,000
   I
7. ********************* (      4)
   I  $30,000 TO $35,000
   I
8. ****** (      1)
   I  $35,000 TO $40,000
   I
9. ******************************* (      6)
   I  OVER $40,000
   I
   I.........I.........I.........I.........I.........I
   0         2         4         6         8        10
   FREQUENCY
```

Figure 2. Histogram of A-E Fees (1984 Dollars).

```
        I
    1.  **************** (       3)
        I   $0 TO $50K
        I
    2.  **************** (       3)
        I   $50K TO $100K
        I
    3.  *************************************************** (       10)
        I   $100K TO $150K
        I
    4.  ************************** (       5)
        I   $150K TO $200K
        I
    5.  ******************************* (       6)
        I   $200K TO $250K
        I
    6.  ********************* (       4)
        I   $250K TO $300K
        I
    7.  ****** (       1)
        I   $300K TO $350K
        I
    8.  **************** (       3)
        I   $350K TO $400K
        I
    9.  *********** (       2)
        I   $400K TO $450K
        I
   11.  ****** (       1)
        I   $500K TO $550K
        I
   12.  ************************** (       5)
        I   OVER $550K
        I
        I.........I.........I.........I.........I.........I
        0         2         4         6         8         10
        FREQUENCY
```

Figure 3. Histogram of Estimated Construction Cost (1984 Dollars).

TABLE III

Distribution of Projects by Year

Year	No. of Projects	Percentage
1980	5	11.4
1981	10	22.7
1982	25	56.8
1983	3	6.8
1984	1	2.3

TABLE IV

Distribution of Projects by Work Class

Code	Work Class	No. of Projects	Percentage
1	New Construction	1	2.3
2	Maintence & Repair	22	51.2
3	Alteration, Modification	9	20.9
4	Equipment Installation	10	23.3
5	Retrofit	1	2.3

Computed Variable and Point Estimate Descriptions

The computed number of disciplines distribution for the data base is shown in Table V. Over 30 percent of the projects, a total of 13, were single discipline. Nineteen projects, or 44.2 percent had three disciplines.

Table VI shows the distribution of lead disciplines calculated for the data base. Twenty projects, or 46.5 percent of the projects, were primarily architectural. Only one project was recorded as a structural/civil lead code.

TABLE V

Distribution of Projects by Number of Disciplines

No. of Disciplines	No. of Projects	Percentage
1	13	31.7
2	8	19.5
3	17	41.5
4	3	7.3

TABLE VI

Distribution of Projects by Lead Discipline

Lead Discipline	No. of Projects	Percentage
Architectural	19	46.4
Structural/Civil	1	2.4
Mechanical	14	34.1
Electrical	7	17.1

The total number of drawings for each case was computed with the average project having almost 9 drawings. The minimum number was one and the maximum was 29.

Two point estimators were computed; the mean of fee as a percentage of estimated construction cost and the mean of dollars per drawing for the data base. The results are shown in Table VII.

The mean fee percentage was calculated as 8.8 percent with a 95 percent confidence interval of 7.3 to 10.2 percent. This gives a confidence interval of plus or minus 17 percent.

TABLE VII

Descriptive Results: Fee as a Percentage of Estimated Construction Cost and Dollars per Drawing.

VARIABLE PERC FEE AS A PERCENTAGE OF ECC

MEAN	.088	STD ERR	.007	STD DEV	.045
VARIANCE	.002	KURTOSIS	3.852	SKEWNESS	1.863
MINIMUM	.032	MAXIMUM	.236	SUM	3.590
C.V. PCT	51.956	.95 C.I.	.073	TO	.102
VALID CASES	41	MISSING CASES	2		

VARIABLE DRAW FEE DOLLARS PER DRAWING

MEAN	2964.130	STD ERR	227.622	STD DEV	1492.620
VARIANCE	2227914.565	KURTOSIS	7.470	SKEWNESS	2.274
MINIMUM	1208.790	MAXIMUM	9424.800	SUM	127457.577
C.V. PCT	50.356	.95 C.I.	2504.769	TO	3423.490
VALID CASES	43	MISSING CASES	0		

This point estimate is not a useful predictor for estimating the initially negotiated fee because it is the percentage of the final fee, which in some cases included modifications. The percentage for initial fee would be slightly lower. For purposes of this research however, it was assumed that the percentage for initial fee would be at least as good an estimator, yielding a simple model that could predict within 17 percent on 95 percent of the projects. These percentages represent the sum of Title Ia and Title Ib services as explained in chapter II.

The mean fee dollars per total number of project drawings was calculated as $2964 in 1984 dollars per drawing. The 95 percent confidence interval was $2504 to $3423 giving a point predictor with plus or minus 15.5 percent. These dollars also represent the sum of Title Ia and Title Ib services.

During these calculations, one case produced a figure of over $15,000 per drawing, which was over three standard deviations from the mean. That case was eliminated as a probable error in data collection. The remaining 43 cases were used for all results in this research.

ANOVA Results

ONE-WAY ANOVA procedures were run for the four data base groupings outlined in chapter II. The Student-Neuman-Keuls (SNK) range test has a predetermined confidence interval of 95 percent in the SPSS routine. This

means in testing the hypothesis that all subgroups are from similar distributions, the test requires 95 percent confidence before separating any subgroups.

Grouped by Work Class. The ANOVA analysis by work class failed to detect any subgroups among the work classes. The F statistic, the test for equality of variance among the groups, was .53 for the groups with the independent variable, dollars per drawing, and .93 for the independent variable, fee as a percentage of estimated construction cost. Since there was only one case of New Construction or Retrofit, those groups did not show in the SNK subsets. More data from those work classes were required for any realistic determination of their homogenity with the data base. From the results of this ANOVA, it is safe to assume that, for this data base, work class is not a significant determinant for dollars per drawing or fee percentage. The ANOVA results are shown in Appendix G.

Grouped by Category Code. The ANOVA analysis by category failed to detect any subgroups among the categories. However the F statistic for category groups by dollars per drawing gave an F probability of only .135. Examination of the output showed the category code subgroup Utility to have a mean dollars per drawing of $4107. Although SNK analysis failed to separate the subgroup, Utility, at the 95 percent confidence level, a separate T-TEST was performed on the data base using a recoded dummy variable group of Not

Utility and Utility. The two-tailed probability was .131, making it safe to assume that, for this data, the category Utility has an effect on the dollars per drawing.

The F statistic for category codes with fee as a percentage of estimated construction cast was only .005. That causes rejection of the hypothesis that all category code subgroups are the same for fee as a percentage of estimated construction cost at a 95 percent confidence level. The SNK analysis again failed to separate any subgroups at the 95 percent confidence level. Examination of the ANOVA results showed that the category subgroup 7, Community Facilities, had a mean fee percentage of 13.28 with a 95 percent confidence interval of 9 to 18 percent. The other categories had mean fee percentages ranging from 6.62 to 7.89. From the results of this ANOVA, it is safe to assume, for this data base, that Community Facilities work has a higher fee percentage than other categories. The results of the ANOVA's and the T-TEST's are shown in Appendix G.

<u>Grouped by Number of Disciplines</u>. The ANOVA for the data, grouped by number of disciplines, with dollars per drawing yeilded an F statistic of .307, making it unlikely that any of the subgroups are substantially different. The SNK tests did not separate any subgroups at the 95 percent confidence interval.

An interesting finding from the results of this ANOVA

was that the mean dollars per drawing was actually higher for single discipline projects than for multidiscipline projects. This is counter to the findings of Moss, Meister, and Ruschman (6) and Herndon (7). They both found that the number of disciplines involved in a project was significant, with single discipline projects being less expensive. A T-TEST of recoded dummy variables of Single Discipline and Multidiscipline yielded a two-tailed probability of .232, with Single Discipline projects having a mean dollars per drawing of $3564 and Multidiscipline projects having a mean of $2765. The author feels this is the result of auto correlation between number of disciplines and total number of drawings. In other words, multidiscipline projects in this fee and construction cost range have more drawings, and, as number of drawings goes up, the cost per drawing goes down. Scattergram plots were made of number of disciplines versus dollars per drawing and total drawings versus dollars per drawing and total drawings versus dollars per drawing. Both showed slight, negative correlations. These scattergrams are shown in Appendix G.

The ANOVA of data grouped by number of disciplines with the fee as a percentage of estimated construction cost yielded an F statistic of .221. The SNK analysis failed to separate any subgroups at the 95 percent confidence level. Examination of the ANOVA results showed that the mean fee as a percentage of estimated construction cost rose as number of disciplines increased. A separate T-TEST was conducted

for the Single Discipline and Multidiscipline dummy variables with fee as a percentage. The results gave a two-tailed probability of .008 making it safe to assume, at the 95 percent confidence level, that fee percentages are different for single discipline and multidiscipline projects. The mean fee percentage for single discipline projects was 6.7 with a standard error of .4. This gives a 95 percent confidence interval of 5.9 to 7.5 for a point estimate within plus or minus 11.88 percent. The mean fee percentage for multidiscipline projects was 9.7 with a standard error of 1.0, giving a 95 percent confidence interval of 7.7 to 11.7 percent. This yields a point estimate with plus or minus 20 percent accuracy. The results of the ANOVA and the T-TEST are shown in Appendix G.

Grouped by Lead Discipline. The ANOVA analysis for the data grouped by lead discipline with dollars per drawing yielded an F statistic of .587, making it safe to assume that little difference exists between dollars per drawing based on the lead discipline of the project. The SNK analysis failed to detect any subgroups at the 95 percent confidence level. Only one case of Structural/Civil as lead discipline made it fail to appear in the SNK subset. More data are required before any realistic determination of homogenity can be made for Structural/Civil as lead discipline.

The ANOVA for lead discipline as a determinant of fee as a percentage of estimated construction cost gave an F

statistic of .682, making it safe to assume that lead discipline is not a determinant of fee percentage for this data base. The results of these ANOVA are shown in Appendix G.

Summary of ANOVA Results. Work Class was not a determinant for dollars per drawing or fee percentage for this data base. There were insufficient data on new construction, which is generally less expensive to design than maintenance and repair or alteration, or retrofit, which is usually more expensive to design than maintenance and repair or alteration.(18)

The subgrouping Utility was a marginal determinant of dollars per drawing within the category group. These groupings were redefined with a dummy variable of Not Utility (labeled Building Work in the SPSS programs and output) and Utility. Also, within the category subgroups, Community facilities was found to be a determinant of fee percentage, with significantly higher fee percentages than other categories of work.

Within the grouped data for Number of Disciplines, a negative correlation was found between the number of disciplines and dollars per drawing. A T-TEST of recoded dummy variables, Single Discipline and Multidiscipline, showed a marginal possibility that single discipline jobs were more expensive in dollars per drawing than multidiscipline jobs. The dummy variables were strong

determinants of fee percentage.

Lead discipline was not found to be a determinant of dollars per drawing or fee percentage.

The ANOVA results and the supplementary tests are shown in Appendix G.

Results of Regression

SPSS SCATTERGRAM (simple regression) and REGRESSION (multiple regression) subroutines were used to determine if linear relationships could be established for predicting or estimating the A-E fee using the number of drawings. The predictive power of these regression procedures is measured by the coefficient of determination or R-squared. The R-squared value is an index of the ability of the independent variable (number of drawings) to predict the A-E fee. Other independent variables, developed during ANOVA analysis, were also used in the regression.

For the first model, a SCATTERGRAM plot was run for total drawings as a predictor of A-E fee. Figure 4 shows the scattergram and indicates a fairly strong linear relationship does exist. The line representing the predictor was manually inserted. The simple regression yielded an R-squared value of .63869, showing that total number of drawings was not a successful predictor of A-E fees based on the predetermined criteria. The regression equation was:

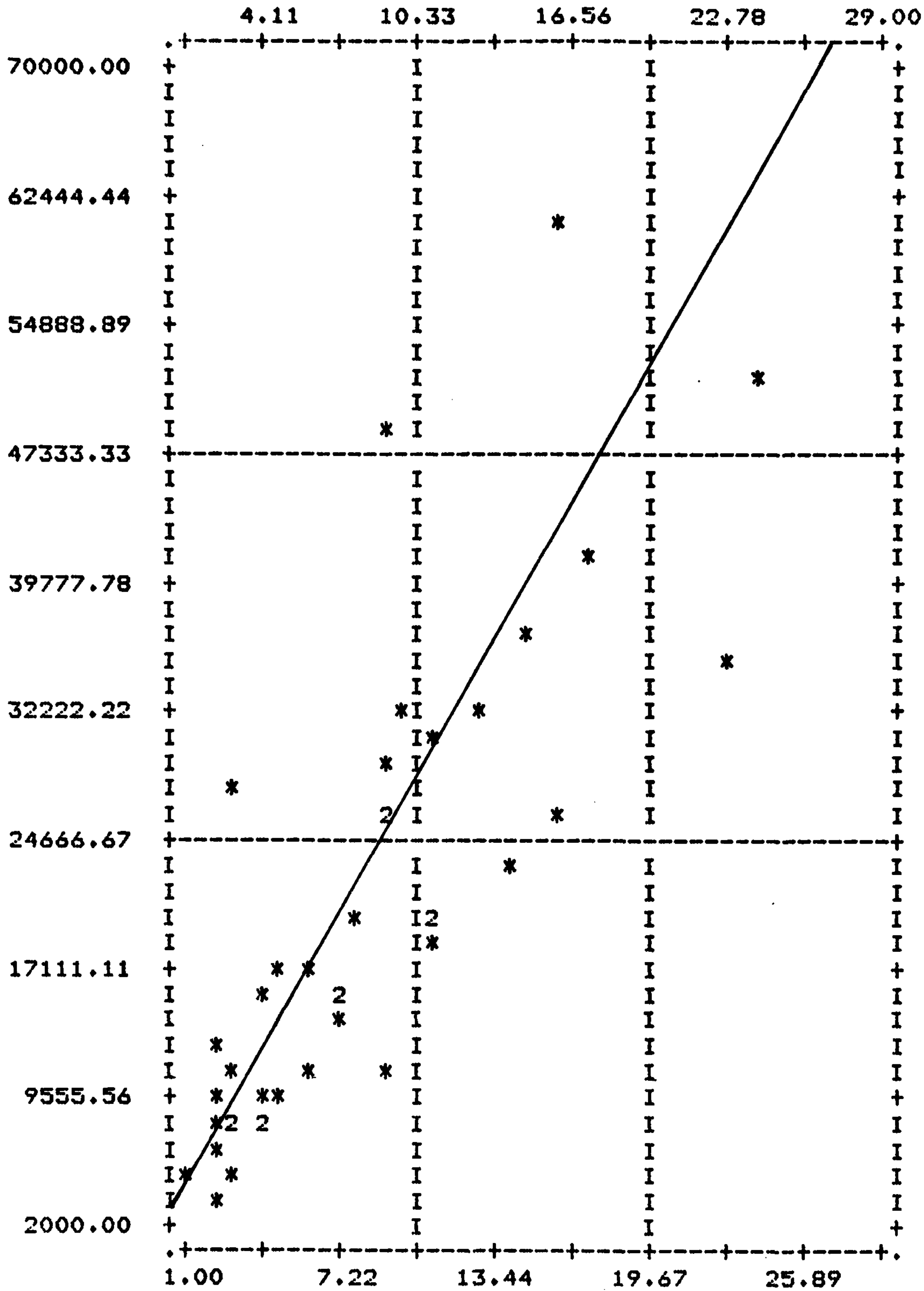

Figure 4. SCATTERGRAM Plot of Total Drawings versus A-E Fee.

$$Y = X(TOTAL) * 1930 + 4938$$

For example 10 drawings would yield a fee of:

$$Y = 10 * 1930 + 4938 = \$24,238$$

whereas the simple point estimate would yield:

10 * $2964 or $29,640.

For the second regression test, the number of drawings by discipline were entered as the independent variables. All four variables were significant at the 95 percent level. The R-squared for this model was .7186. The model was in the form:

$$\text{A-E fee} = 2159X1 + 5670X2 + 2296X3 + 2999X4 + 1539.$$

If, for example, the 10 drawings were divided:

4 - Architectural
1 - Structural/Civil
3 - Mechanical
2 - Electrical

this model would yield a fee of $27,192. Results of regressions are shown in Appendix H.

The standard error for the coefficients in this model were relatively small compared to the coefficients except for Structural/Civil Drawings. The data base had only 13 Structural/Civil drawings giving a mean coefficient of 5670 and a standard error of 2123. While the regression results for the other three variables was fairly close to a reasonable dollar value, the coefficient for Structural/Civil drawings appeared inflated.

Because of the small number of Structural/Civil

drawings in the data, another regression was run with those projects which had no Structural/Civil drawings. This model used 36 cases to yield a final R-squared of .724, an improvement over the earlier model which had an R-squared of .675 at the third variable.

Neither of these multiple regression models was a great improvement over the simple regression model using total drawings. A stepwise regression was attempted using the following independent variables:

X1 Total Number of Drawings
X2 Estimated Construction Cost
X3 Community Facility or Not Community Facility
X4 Log 10 of Estimated Construction Cost
X5 Building or Utility Work
X6 Single or Multidiscipline

Log 10 of Estimated Construction Cost was introduced to see if it was a better predictor over the fee range than the Estimated Construction Cost. This relationship is suggested by the AIA fee chart (Figure 1 in Chapter I), which shows a logrithmic relationship.

Community Facility, Building or Utility, and Single or Multidiscipline are category or dummy variables with values of zero or one. They would enter the equation to explain any discriminating power as discovered in the ANOVA analyses.

The most useful model generated by the stepwise regression yielded an R-squared of .871 - which is a fairly powerful predictor with only two independent variables. The

model was:

```
A-E fee = X1(TOTAL DRAWINGS) * 2002.79 +
          X2(ESTIMATED CONST COST) *.0237 -
          1068.55
```

The next variable entering the equation was Community or Not Community (X3) with a significance of .403 and a change of R-squared of only .002.

<u>Summary of Regression Results</u>. The best model generated by regression was the two variable model using total number of drawings and estimated construction cost. The regression attempts using the number of drawings by discipline was not as successful. A larger data base would probably yield better results with this model. The size of the data base limited the number of variables that could be entered as estimators with any significance. Results of regression models are shown in Appendix H.

<u>Summary of Cost Models</u>

Several cost models were developed which could predict the A-E fee based on number of drawings. The simplest point estimator was the mean dollars per drawing model, yielding the following equation:

A-E fee= number of drawings * $2964

with a 95 percent confidence interval of $2504 to $3423 per drawing.

The simple regression model gave an equation of:

A-E fee = total drawings * 1930 + 4938

with an R-squared of .639.

The multiple regression model by discipline yielded the equation:

A-E fee = 2159X1 + 5670X2 + 2296X3 + 1539

and an R-squared of .719.

The final regression model yielded:

A-E fee = total drawings * 2002.79 + .0237 * estimated const cost - 1068.55

and an R-squared of .871.

Adjustments to the A-E fee based on the ANOVA results are summarized in Table VIII.

TABLE VIII

Adjustments for Project Characteristics

	Dollars per Drawing		Fee Percentage	
	lower	higher	lower	higher
Building Work	X	-	-	-
Utility Work	-	X	-	-
Community Facility	-	-	-	X
Not Community Facility	-	-	X	-
Single Discipline	-	-	X	-
Multidiscipline	-	-	-	X
More than 9 Drawings	X	-	-	-
Less than 9 Drawings	-	X	-	-

Appendix I outlines a reverse breakdown procedure which may be used to derive detailed analysis estimates from the model derived fee.

IV. Conclusions and Recommendations

This chapter is divided into three sections. The first section addresses the research questions and the general hypothesis set forth in Chapter I. The second part discusses the general conclusions of the overall research. The third section outlines recommendations for future research and general recommendations based on this research.

Research Questions Answered

This research demonstrated that useful cost models could be developed by statistical analysis of a base-level contract data base. The specific research questions are addressed below.

1. Can a relationship between A-E fee and number of drawings be established from a base-level data base?

Several models with reasonably strong relationships were developed. These models were not compared with traditional estimating techniques to measure any improvement in accuracy, but, combined with traditional techniques, the models can provide a point of departure for estimating fees. The models were:

1. The simple point estimate model:

A-E fee= number of drawings * $2964

with a 95 percent confidence interval of \$2504 to \$3423 per drawing.

2. The simple regression model:

$$\text{A-E fee} = \text{total drawings} * 1930 + 4938$$

with an R-squared of .639.

3. The multiple regression model by discipline:

$$\text{A-E fee} = 2159X1 + 5670X2 + 2296X3 + 2999X4 + 1539$$

and an R-squared of .719.

4. And, the final regression model:

$$\text{A-E fee} = \text{total drawings} * 2002.79 + .0237 * \text{estimated const cost} - 1068.55$$

and an R-squared of .871.

The relationship between number of drawings and A-E fees was more powerful for total number of drawings than for drawings separated by discipline. A larger data base might allow a stronger relationship to be developed between drawings by discipline and A-E fees.

This model could provide more support to the cartooning estimating technique and would be more flexible for the project categories and work classes.

2. Is the relationship powerful and accurate enough to predict or estimate fees for future projects?

The final regression model yielded an R-squared of over .8, which is generally considered a reliable estimator. Combined with experience and judgement of a good estimator, the model can help establish fair and reasonable fees. The

fees may be closer to fair and reasonable than traditionally derived fees because they are founded on the data of the "market place".

General Hypothesis Examined

The general hypothesis of this research was:

A relationship exists between the number of drawings by discipline produced by an A-E contract and the final negotiated fee.

The hypothesis must be rejected at the predetermined R-squared criteria. However, if the relationship by discipline is moved from the hypothesis, a successful model was developed with a strong relationship between total number of drawings and A-E fee.

General Conclusions

Each construction project and design of a construction project is unique in some respect. The uniqueness of design requirements requires that judgement and experience remain primary factors in developing fair and reasonable estimates of remuneration for design services. The intention of this cost model formulation is to supplement, not replace, experience and judgement in developing good A-E fee estimates. The usefulness of these

models depends on the estimator's skill at estimating the number of drawings required for a project.

Also, each data base of A-E designed projects is unique. The models developed in this research only apply to the projects of the 2750th CES, at Wright-Patterson AFB, Ohio, and only within the range of fees and construction cost represented in the data base.

Cost models derived by statistical methods from a base-level data base can yield good estimating formulas which may provide a point of departure for an experienced estimator.

Recommendations

There are many methods of enhancing the capabilities of the models produced in this research. Outlined below are several recommendations for further research.

Recommendations for Future Research. This research was limited because of the limited size of the data base. A regional approach, lumping the data of several bases and using a city cost index might yield better results. Also, inconsistencies, such as a single base consistently over or under paying A-E fees, could be corrected by comparing similar fees at other locations. Also, models might be developed for specialized projects - like family housing renovations - for the Air Force Regional Civil Engineers.

An area not addressed in this research, but receiving

high level government and private interest, is the effects of the six percent limit on Title Ib services. Another area, which is not addressed here but deserves further research, is the Brook's Bill and its effects on the cost of procuring A-E services.

General Recommendations. In order to develop cost models, an organized data base, the statistical programs, and computer hardware must be accessible to the estimating organization. The data base must be continually updated as new A-E contract data arrives.

The data base used for this research was the minimum necessary for developing the drawing/A-E fee relationship. A larger data base might be necessary to uncover other relationships not discovered by this research.

If the use of A-E firms grows in the next few years as it has in the past few, cost model formulation may be a necessary tool for developing A-E fee estimates. With lack of competition among A-E firms, the advantage the government has is a historical data base with all the data necessary for determining fair and reasonable fees.

Appendix A: The Brook's Bill; Public Law 92-582

An Act to amend the Federal Property and Administrative Services Act of 1949 in order to establish Federal Policy concerning the selection of firms and individuals to perform architectural, engineering, and related services for the Federal Government.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That:

The Federal Property and Administrative Services Act of 1949 (49 U.S.C. 471 et seq.) is amended by adding at the end thereof the following new title:

TITLE IX - SELECTION OF ARCHITECTS AND ENGINEERS

DEFINITIONS

Sec. 901. As used in this title-

(1) The term "firm" means any individual firm, partnership, corporation, association, or other legal entity permitted by law to practice the professions of architecture or engineering.

(2) The term "agency head" means the Secretary, Administrator, or head of a department, agency, or bureau of the Federal Government.

(3) The term "architectural and engineering services"

includes those professional services of an architectural and or engineering nature as well as incidental services that members of these professions and those in their employ may logically or justifiably perform.

POLICY

Sec.902. The Congress hereby declares it to be the policy of the Federal Government to publicly announce all requirements for architectural and engineering services, and to negotiate contracts for architectural and engineering services on the basis of demonstrated competence and qualification for the type of professional services required and at fair and reasonable prices.

REQUESTS FOR DATA ON ARCHITECTURAL AND ENGINEERING SERVICES

Sec. 903. In the procurement of architectural and engineering services, the agency head shall encourage firms engaged in the lawful practice of their profession to submit annually a statement of qualifications and performance data. The agency head, for each proposed project, shall evaluate current statements of qualifications and performance data on file with the agency, together with those that may be submitted by other firms regarding the proposed project, and shall conduct discussions with no less than three firms regarding anticipated concepts and the relative utility of alternative methods of approach for furnishing the required services and then shall select therefrom, in order of

preference, based upon criteria established and published by him, no less than three of the firms deemed to be the most highly qualified to provide the services required.

NEGOTIATION OF CONTRACTS FOR ARCHITECTURAL AND ENGINEERING SERVICES

Sec. 904. (a) The agency head shall negotiate a contract with the highest qualified firm for architectural and engineering services at compensation which the agency head determines is fair and reasonable to the Government. In making such determination, the agency head shall take into account the estimated value of the services to be rendered, the scope, complexity, and professional nature thereof.

(b) Should the agency head be unable to negotiate a satisfactory contract with the firm considered to be the most qualified, at a price he determines to be fair and reasonable to the Government, negotiations with that firm should be formally terminated. The agency head should then undertake negotiations with the second most qualified firm. Failing accord with the second most qualified firm, the agency head should terminate negotiations. The agency head should then undertake negotiations with the third most qualified firm.

(c) Should the agency head be unable to negotiate a satisfactory contract with any of the selected firms, he shall select additional firms in order of their competence and qualification and continue negotiations in accordance with this section until an agreement is reached.

Appendix B: Tactical Air Command A-E Estimating Form

GOVERNMENT ESTIMATE

Government Estimate for Architect- Engineer (A-E) services in connection with the (Feasibility Study for) (Design of) (Modification of Contract No ________________) ______________________________

(Project & Location)

____

____

(A-E) (Location of A-E)

This Government estimate has been prepared in accordance with the OCE Contract Negotiation Manual.

Travel and per diem allowances used herein are within limits established by Joint Travel Regulations.

The overhead rate used herein is substantiated by

PREPARED BY: APPROVED BY:

Department of the Air Force
Langley AFB VA 23665

____

(Date)

1424E
2 Nov 83

PAGE 1 OF 7

A. **GOVERNMENT ESTIMATE:**

1. ESTIMATED LUMP SUM A-E FEE:

a. Field Investigation of Existing Conditions

(1) Direct Labor Cost:

Supervision ______MH @ $_______ = $______
Arch/Engr ______MH @ $_______ = $______
Technician ______MH @ $_______ = $______

Total Direct Labor Cost $____________

(2) OH on Direct Labor (____%), General and Administrative (_____%) Total________% ____________

(3) Materials, Supplies ____________

(4) Travel ____________

(5) Other ____________

Total Estimated A-E Cost $____________

(6) Profit (________%) ____________

Total Estimated A-E Fee $____________

SAY $____________

b. Topographic Field Survey

(1) Direct Labor Cost:

Supervision ________MH @ $________ = $________
Field Work ________MH @ $________ = $________
Office Work ________MH @ $________ = $________

Total Direct Labor Cost $____________

(2) OH on Direct Labor (______%), General and Administrative (_______%) Total_______% ____________

(3) Material, Supplies ____________

(4) Travel ____________

(5) Other ____________

Total Estimated A-E Cost ____________

(6) Profit (______________%) ____________

Total Estimated A-E Fee $____________

SAY $____________

c. (Concept) (Preliminary) Design

(1) Direct Labor Cost:

	No of Dwg/Pg	Man-Hours	Av Rate	Total
Supervision	______	________	$_____	$______
Architect	______	________	$_____	$______
Struc Engr	______	________	$_____	$______
Mech Engr	______	________	$_____	$______
Elec Engr	______	________	$_____	$______
Civil Engr	______	________	$_____	$______
Draftsmen	______	________	$_____	$______
Estimator	______	________	$_____	$______
Specifier	______	________	$_____	$______
Typist	______	________	$_____	$______

Total Direct Labor Cost $________

(2) OH on Direct labor (____%), General and Administrative (_____%) Total_____% ________

(3) Materials, Supplies ________

(4) Travel ________

(5) Others (Renderings, Reproduction, Printing, Consultants, etc) (Describe in detail) ________

Total Estimated A-E Cost $________

(6) Profit (_____%) ________

Total Estimated A-E Fee $________

SAY $________

PAGE 3 OF 7

d. Final Design (Optional)

(1) Direct Labor Cost:

	No of Dwg/Pg	Man-Hours	Av Rate	Total
Supervision	____	______	$____	$____
Architect	____	______	$____	$____
Struc Engr	____	______	$____	$____
Mech Engr	____	______	$____	$____
Elec Engr	____	______	$____	$____
Civil Engr	____	______	$____	$____
Draftsmen	____	______	$____	$____
Estimator	____	______	$____	$____
Specifier	____	______	$____	$____
Typist	____	______	$____	$____

Total Direct Labor Cost $______

(2) OH on Direct labor (____%), General and Administrative (_____%) Total_____% ______

(3) Materials, Supplies ______

(4) Travel ______

(5) Others (Renderings, Reproduction, Printing, Consultants, etc) (Describe in detail) ______

Total Estimated A-E Cost $______

(6) Profit (_____%) ______

Total Estimated A-E Fee $______

SAY $______

e. Checking of Shop Drawings (Optional)

(1) Direct Labor Cost:

Supervision ______MH @ $______ = $______
Arch/Engr ______MH @ $______ = $______
Technician ______MH @ $______ = $______

Total Direct Labor Cost $______

(2) OH on Direct Labor (____%), General and Administrative (____%) Total______% ______

(3) Materials, Supplies ______

(4) Travel ______

(5) Other ______

Total Estimated A-E Cost $______

(6) Profit (______%) ______

Total Estimated A-E Fee $______

SAY $______

f. Topographic Field Survey

(1) Direct Labor Cost:

Supervision ______MH @ $______ = $______
Field Work ______MH @ $______ = $______
Office Work ______MH @ $______ = $______

Total Direct Labor Cost $______

(2) OH on Direct Labor (____%), General and Administrative (____%) Total______% ______

(3) Material, Supplies ______

(4) Travel ______

(5) Other ______

Total Estimated A-E Cost ______

(6) Profit (______%) ______

Total Estimated A-E Fee $______

SAY $______

PAGE 5 OF 7

2. ESTIMATED UNIT COST A-E FEE:

a. Site Visits/Visit (Optional)

(1) Direct Labor Cost:

Arch/Engr ______MH @ $______ = $______

(Field__________hrs (Office__________hrs) $________

(2) OH on Direct Labor (____%), General and Administrative (____%) Total______% $________

(3) Travel $________
Total Estimated A-E Cost/Visit $________

(4) Profit (______%) ________

Total Estimated A-E Fee/Visit $________*

SAY $________

*Plus per diem and travel costs in accordance with Joint Travel Regulations, if travel is not included in the fee.

B. DETERMINATION OF RATE OF PROFIT:

1. ESTIMATED LUMP SUM A-E COSTS:

a. Field Investigation $________

b. Topographic Investigation ________

c. (Concept) (Preliminary) Design ________

d. Final Design (Optional) ________

e. Checking of Shop Drawings (Optional) ________

f. Preparation of As-Built Drawings (Optional) ________

Total Estimated Lump Sum A-E Costs $________

2. NEGOTIATION MANUAL, PART I, 7 NOV 56:

a. Basic Rate of Profit on Curve__________at Estimated Lump Sum Costs of $________ = ____%.

b. Basic Rate of Profit of ____% X Complexity Factor of________ = ____% Rate of Profit to be Applied to Estimated A-E Costs.

C. <u>SUMMARY OF GOVERNMENT ESTIMATE:</u>

1. ESTIMATED LUMP SUM A-E FEE:

a. Field Investigation	$________
b. Topographic Investigation	________
c. (Concept) (Preliminary) Design	________
d. Final Design (Optional)	________
e. Checking of Shop Drawings (Optional)	________
f. Preparation of As-Built Drawings (Optional)	________
Total Estimated Lump Sum A-E Costs	$________

2. ESTIMATED UNIT COST A-E FEE:

Site Visits/Visit (Optional)	$________*

*Plus per diem and travel costs in accordance with Joint Travel Regulations, if travel is not included in the fee.

Appendix C: Variables Considered But Not Used

1. Project Complexity
2. Project Modularity
3. Number of Pages in Statement of Work
4. Number of Pages in Specifications
5. Period of Performance of A-E Contract
6. A-E Experience with Government Contracts
7. Location of A-E (Miles from Base)
8. Open-ended or not Open-ended Contract

Appendix D: Data Collection Worksheet

1. PROJ. NO. ____________

2. YEAR ______

3. A-E FEE ________________

****

4. ARCH DRAWINGS ____

5. STRUCTURAL ____

6. CIVIL ____

7. ELECTRICAL ____

8. HVAC ____

9. PLUMBING ____

10. FIRE ____

****

11. WORK CODE ____

12. CAT CODE ____

13. ECC ________

****

12. WORK CODES

1 - New Construction

2 - Maintenance and Repair

3 - Alteration

4 - Equipment Installation

5 - Retrofit (Safety, Pollution, Energy)

13. CATEGORY CODES

1 - Operations and Training

2 - Maintenance

3 - Research

4 - Supply and Warehouse

5 - Medical

6 - Administration

7 - Community

8 - Utilities

9 - Pavements and Grounds

0 - Family Housing

Appendix E: Raw Data

```
1,83,28964,4,0,0.3,1.3,0,256.5,2,6
2,82,23749.4.1,0,2,2,0,0,159.5,3,7
3,82,54439,9,0,0,3,2,2,0,350.0,2,7
4,82,26371.2,0,0,2,5,0,0,370.9,4,8
5,82,7411,1,0,0,1,0,1,0,69.7,2,6
6,82,7701,1,0,1,2,0,0,0,112.8,1,4
7,82,23569,6,0,0,4,3,3,0,100.0,2,7
8,82,17332,2,0,0,3,1,2,0,220.0,2,7
9,82,16360,4,0,1,2,2,2,0,220.0,2,6
10,82,7877,1,0,0,1,0,0,0,100.0,4,6
11.82,46377,13,2,0,3,3,3,0.539.4,3.7
12,82,77049,13.0,0,6.6,4,0,461.0,2,7
13,82,15890,0,0,0,2,3,0,0,130.0,4,6
14,82,43590,0,0,4,0.5,0,0,1376.0,2,8
15,82,4665,2,0,0,1,0.0,0.20.0,4.7
16,82.18578,0,0,0,5.6,0.0,516.1,4,8
17.82.7272,3,0,0,0,0,0,181.9,2,1
18,81,6402,2,0,0,1,0,1,0,93.7,2,6
19,82,4192,1,0,0,0,0,0,86.3,2,6
20,81,3043,2,0,0,0,0,0,58.8,2,6
21,81,28852,9,0,0,4,7,3,0,0,3,6
22,81,8159,0,0,0,0,0,4,0,114.0,4,8
23,81,8002,0,0,0,0,0,0,5,124.9,5,4
24,81,5828,0,0,0,2,0,0,0,91.6,4,8
25,81,8991,5,0,0,2,1,0,1,92.7,3,7
26,81,11328,0,0,0,1,6,0,0,140.0,4,8
27.82,13549,4,0,0,1,1,1,0,0,3,1
28,81,21674,0,0.2,1,0,6,0,184.3,4,8
29,82,28441,5,0,0,2,3,0,0,360.0,3,6
30,82,29012,5,0,0,3,3,1,1,336.5,3,1
31,81,13863,0,0,0,3,3.0,0,236.4,4.6
32,80.11728,2.2,0,0,0.0,0,220.0,2,6
33,80,20944,0,0,0,0,3,0,0,295.0,2,8
34,80,6019,2,0,0,0,0,0.0,110.0,2,6
35,80,8106.3,0,0,2,1,0,0.150.0,2,6
36,80,9000,0,0.0,0,2,0,0,125.0,2,8
37,82,17734,11.0,0,0,0,0,0,221.6,2,7
38,82,10401,3,0,0,0,0,0,108.0,2,6
39,82,20884,14,0,0,0,0,0,262.2,2,6
40,82,15849,1,0,0,0,0,0,200.7,2,6
41,83,14886,7,0,0,0,0,0,189.0,2,6
42,82,33145,8.0,0,2,5,0,0,300.0,3,1
43,83,74188,9,0,0,4,2,2,0,1616.1,2,7
44,84,41692,7,0,0,7,0,3,0,697.0,3,6
END OF FILE
```

Appendix F: SPSS Programs

```
RUN NAME         AE FEE ANALYSIS
PRINT BACK       CONTROL
VARIABLE LIST    PROJNO,YR,FEE,ARCH,STRUC,CIV,ELEC,HVAC
                 PLUMB,FIRE,ECC,WC,CAT
INPUT MEDIUM     CARD
N OF CASES       43
INPUT FORMAT     FREEFIELD
MISSING VALUES   ECC(0)
COMPUTE          TOT=ARCH+STRUC+CIV+ELEC+HVAC+PLUMB+FIRE
COMPUTE          MECH=HVAC+PLUMB+FIRE
COMPUTE          STCIV=STRUC+CIV
IF               (YR EQ 80)IFEE=FEE*1.35
IF               (YR EQ 81)IFEE=FEE*1.21
IF               (YR EQ 82)IFEE=FEE*1.12
IF               (YR EQ 83)IFEE=FEE*1.05
IF               (YR EQ 84)IFEE=FEE
IF               (YR EQ 80)IECC=ECC*1.35
IF               (YR EQ 81)IECC=ECC*1.21
IF               (YR EQ 82)IECC=ECC*1.12
IF               (YR EQ 83)IECC=ECC*1.05
IF               (YR EQ 84)IECC=ECC
COMPUTE          PERC=FEE/ECC/1000
ASSIGN MISSING   PERC(0)
COMPUTE          DRAW=IFEE/TOT
COMPUTE          CAT1=0
IF               (CAT LT 8)CAT1=1
IF               (CAT EQ 8)CAT1=2
COMPUTE          FEE1=IFEE
RECODE           FEE1(0 THRU 5000=1)(5001 THRU 10000=2)
                 (10001 THRU 15000=3)(15001 THRU 20000=4)
                 (20001 THRU 25000=5)(25001 THRU 30000=6)
                 (30001 THRU 35000=7)(35000 THRU 40000=8)
                 (40001 THRU HIGHEST=9)
COMPUTE          ECC1=IECC
COUNT            NUM=ARCH,STCIV,MECH,ELEC(1 THRU 20)
RECODE           ECC1(0 THRU 50=1)(50.1 THRU 100=2)
                 (100.1 THRU 150=3)(150.1 THRU 200=4)
                 (200.1 THRU 250=5)(250.1 THRU 300=6)
                 (300.1 THRU 350=7)(350.1 THRU 400=8)
                 (400.1 THRU 450=9)(450.1 THRU 500=10)
                 (500.1 THRU 550=11)(550.1 THRU HIGHEST=12)
IF               (ELEC GE ARCH AND STCIV AND MECH)LEAD=4
IF               (MECH GT ELEC AND GE STCIV AND ARCH)LEAD=3
IF               (STCIV GT ELEC AND MECH AND GE ARCH)LEAD=2
IF               (ARCH GT STCIV AND MECH AND ELEC)LEAD=1
```

```
MISSING VALUES PERC(0),DRAW(0)
VAR LABELS     PROJNO,PROJECT NUMBER/
               YR,YEAR/
               FEE,A-E FEE/
               IFEE,A-E FEE 84 DOLLARS/
               ARCH,NUMBER OF ARCHITECTURAL DRAWINGS/
               STRUC,NUMBER OF STRUCTURAL DRAWINGS/
               CIV,NUMBER OF CIVIL DRAWINGS/
               ELEC,NUMBER OF ELECTRICAL DRAWINGS/
               HVAC,NUMBER OF HVAC DRAWINGS/
               PLUMB,NUMBER OF PLUMBING DRAWINGS/
               FIRE,NUMBER OF FIRE PROTECTION DRAWINGS/
               MECH,NUMBER OF MECHANICAL DRAWINGS/
               STCIV,NUMBER OF STRUCTURAL CIVIL DRAWINGS/
               LEAD,LEAD DISCIPLINE/
               ECC,ESTIMATED CONSTRUCTION COST/
               IECC,ESTIMATED CONSTRUCTION COST 84 DOLLARS/
               WC,WORK CLASS/
               CAT,CATEGORY CODE/
               TOT,TOTAL NUMBER OF DRAWINGS/
               PERC,FEE AS A PERCENTAGE OF ECC/
               DRAW,FEE DOLLARS PER DRAWING/
               CAT1,BUILDING OR UTILITY WORK/
               NUM,NUMBER OF DISCIPLINES/
VALUE LABELS   WC(1)NEW CONSTRUCTION(2)MAINTENANCE AND REPAIR
               (3)ALTERATION,MODIFICATION,EXPANSION
               (4)EQUIPMENT INSTALLATION(5)RETROFIT/
               FEE1(1)$0 TO $5000(2)$5000 TO $10,000
               (3)$10,000 TO $15,000(4)$15,000 TO $20,000
               (5)$20,000 TO $25,000(6)$25,000 TO $30,000
               (7)$30,000 TO $35,000(8)$35,000 TO $40,000
               (9)OVER $40,000/
               ECC1(1)$0 TO $50K(2)$50K TO $100K
               (3)$100K TO $150K(4)$150K TO $200K
               (5)$200K TO $250K(6)$250K TO $300K
               (7)$300K TO $350K(8)$350K TO $400K
               (9)$400K TO $450K(10)$450K TO $500K
               (11)$500K TO $550K(12)OVER $550K/
               CAT1(1)BUILDING WORK(2)UTILITY WORK/
               LEAD(1)ARCHITECTURAL(2)STRUCTURAL CIVIL
               (3)MECHANICAL(4)ELECTRICAL/
```

```
TASK NAME       DESCRIPTION OF DATA BASE
CONDESCRIPTIVE  PERC,DRAW,TOT,NUM,IFEE,IECC
STATISTICS      ALL
FREQUENCIES     GENERAL=ECC1,FEE1,WC,CAT1,NUM,LEAD
OPTIONS         3,8
STATISTICS      ALL
T-TEST          GROUPS=CAT1(1,2)/VARIABLES=DRAW,PERC
OPTIONS         2
READ INPUT DATA
END OF FILE

T-TEST          GROUPS=CAT1(0,1)/VARIABLES=DRAW,PERC
OPTIONS         2
T-TEST          GROUPS=NUM1(0,1)/VARIABLES=DRAW,PERC
OPTIONS         2
ONEWAY          DRAW,PERC BY NUM(1,4)/
                RANGES = SNK/
OPTIONS         2
STATISTICS      1
ONEWAY          DRAW,PERC BY WC(1,5)/
                RANGES = SNK/
OPTIONS         2
STATISTICS      1
ONEWAY          DRAW,PERC BY CAT(0,9)/
                RANGES = SNK/
OPTIONS         2
STATISTICS      1
ONEWAY          DRAW,PERC BY LEAD(1,4)/
                RANGES = SNK/
OPTIONS         2
STATISTICS      1
SCATTERGRAM     DRAW(0,10000) WITH NUM(1,5),TOT(1,25)
OPTIONS         2
STATISTICS      ALL
SCATTERGRAM     IFEE(2000,70000) WITH TOT
OPTIONS         2
STATISTICS      ALL
REGRESSION      VARIABLES=IFEE,ARCH,STCIV,MECH,ELEC/
                REGRESSION=IFEE WITH ARCH,STCIV,MECH,ELEC/
STATISTICS      ALL
REGRESSION      VARIABLES=IFEE,CAT1,TOT,NUM1/
                REGRESSION=IFEE WITH CAT1,TOT,NUM1(1)/
STATISTICS      ALL
READ INPUT DATA
END OF FILE
```

Appendix G: ANOVA Results

TABLE IX

ANOVA Table: Fee in Dollars per Drawing versus Work Class

VARIABLE DRAW FEE DOLLARS PER DRAWING
BY WC WORK CLASS

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB
BETWEEN GROUPS	4	7443327.261	1860831.815	.804	.530
WITHIN GROUPS	36	83280669.088	2313351.919		
TOTAL	40	90723996.349			

GROUP	COUNT	MEAN	STAND. DEV.	STAND. ERROR	MIN.	MAX.	95 PERCENT CONF INT FOR MEAN
GRP 1	1	2156.28	0	0	2156.28	2156.28	2156.28 TO 2156.28
GRP 2	22	3372.33	1879.55	400.72	1649.83	9424.80	2538.99 TO 4205.67
GRP 3	7	2420.10	634.47	239.81	1208.79	3185.39	1833.31 TO 3006.88
GRP 4	10	2854.72	861.45	272.41	1741.60	4411.12	2238.48 TO 3470.96
GRP 5	1	1936.48	0	0	1936.48	1936.48	1936.48 TO 1936.48
TOTAL	41	3018.83			1208.79	9424.80	

TABLE X

ANOVA Table: Fee as a Percentage of Estimated Construction Cost versus Work Class

VARIABLE PERC FEE AS A PERCENTAGE OF ECC
BY WC WORK CLASS

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB
BETWEEN GROUPS	4	.002	.000	.212	.930
WITHIN GROUPS	36	.081	.002		
TOTAL	40	.083			

GROUP	COUNT	MEAN	STAND. DEV.	STAND. ERROR	MIN.	MAX.	95 PERCENT CONF INT FOR MEAN
GRP 1	1	.07	0	0	.07	.07	.07 TO .07
GRP 2	22	.08	.05	.01	.03	.24	.06 TO .11
GRP 3	7	.10	.03	.01	.06	.15	.07 TO .12
GRP 4	10	.09	.06	.02	.04	.23	.05 TO .13
GRP 5	1	.06	0	0	.06	.06	.06 TO .06
TOTAL	41	.09			.03	.24	

TABLE XI

ANOVA Table: Fee in Dollars per Drawing versus Category Code

VARIABLE DRAW — FEE DOLLARS PER DRAWING
BY CAT — CATEGORY CODE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB
BETWEEN GROUPS	4	15695873.650	3923968.413	1.883	.135
WITHIN GROUPS	36	75028122.698	2084114.519		
TOTAL	40	90723996.349			

GROUP	COUNT	MEAN	STAND. DEV.	STAND. ERROR	MIN.	MAX.	95 PERCENT CONF INT FOR MEAN
GRP 1	3	2563.07	132.05	76.24	2474.83	2714.88	2235.03 TO 2891.10
GRP 4	2	2046.38	155.42	109.90	1936.48	2156.28	650.00 TO 3442.77
GRP 6	17	2923.85	1011.96	245.44	1665.75	4695.04	2403.55 TO 3444.15
GRP 7	10	2532.07	1056.33	334.04	1208.79	4582.20	1776.42 TO 3287.71
GRP 8	9	4107.08	2463.27	821.09	1891.58	9424.80	2213.65 TO 6000.52
TOTAL	41	3018.83			1208.79	9424.80	

TABLE XII

T-TEST Table: Utility versus Not Utility for Dollars per Drawing

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
DRAW FEE DOLLARS PER DRAWING				
GROUP 1	32	2712.7538	959.263	169.575
GROUP 2	9	4107.0831	2463.274	821.091

		POOLED VARIANCE ESTIMATE			SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
6.59	.000	-2.63	39	.012	-1.66	8.69	.131

TABLE XIII

ANOVA Table: Fee as a Percentage of Estimated Construction Cost versus Category Code

VARIABLE PERC   FEE AS A PERCENTAGE OF ECC
BY CAT   CATEGORY CODE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB
BETWEEN GROUPS	4	.028	.007	4.489	.005
WITHIN GROUPS	36	.055	.002		
TOTAL	40	.083			

GROUP	COUNT	MEAN	STAND. DEV.	STAND. ERROR	MIN.	MAX.	95 PERCENT CONF INT FOR MEAN
GRP 1	3	.08	.04	.02	.04	.11	-.01 TO .17
GRP 4	2	.07	.00	.00	.06	.07	.04 TO .09
GRP 6	17	.08	.02	.01	.05	.12	.06 TO .09
GRP 7	10	.13	.07	.02	.05	.24	.09 TO .18
GRP 8	9	.07	.03	.01	.03	.12	.05 TO .09
TOTAL	41	.09			.03	.24	

TABLE XIV

ANOVA Table: Fee in Dollars per Drawing versus Number of Disciplines

VARIABLE DRAW — FEE DOLLARS PER DRAWING
BY NUM — NUMBER OF DISCIPLINES

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB
BETWEEN GROUPS	3	8320751.672	2773583.891	1.245	.307
WITHIN GROUPS	37	82403244.677	2227114.721		
TOTAL	40	90723996.349			

GROUP	COUNT	MEAN	STAND. DEV.	STAND. ERROR	MIN.	MAX.	95 PERCENT CONF INT FOR MEAN
GRP 1	13	3564.34	2203.65	611.18	1670.72	9424.80	2232.68 TO 4895.99
GRP 2	8	3217.53	1344.91	475.50	1741.60	5424.53	2093.16 TO 4341.90
GRP 3	17	2641.75	814.81	197.62	1208.79	4582.20	2222.82 TO 3060.69
GRP 4	3	2261.81	650.35	375.48	1665.75	2955.43	646.23 TO 3877.40
TOTAL	41	3018.83			1208.79	9424.80	

```
               1.44       2.33       3.22       4.11       5.00
         .+-----+----+-----+----+-----+----+-----+----+-----+.
10000.00 +                I               I                +
         I                I               I                I
         I                I               I                I
         I*               I               I                I
         I                I               I                I
 8888.89 +                I               I                +
         I                I               I                I
         I                I               I                I
         I                I               I                I
         I                I               I                I
 7777.78 +                I               I                +
         I                I               I                I
         I                I               I                I
         I                I               I                I
         I                I               I                I
 6666.67 +-------------------------------------------------+
         I                I               I                I
         I                I               I                I
         I*               I               I                I
         I                I               I                I
 5555.56 +                I               I                +
         I            *   I               I                I
         I                I               I                I
         I                I               I                I
         I*               I       *       I                I
 4444.44 +            *   I               I                +
         I                I               I                I
         I*           *   I               I                I
         I*               I       *       I                I
         I*           *   I               I                I
 3333.33 +------------------------*------------------------+
         I                I       *       I                I
         I            *   I       2       I    *           I
         I*               I       2       I                I
         I*               I       4       I                I
 2222.22 +*               I       2       I    *           +
         I*           2   I       *       I                I
         I3           *   I       *       I                I
         I                I       2       I    *           I
         I                I               I                I
 1111.11 +                I       *       I                +
         I                I               I                I
         I                I               I                I
         I                I               I                I
         I                I               I                I
       0 +                I               I                +
         .+-----+----+-----+----+-----+----+-----+----+-----+.
          1.00      1.89       2.78       3.67       4.56
```

Figure 5. SCATTERGRAM Plot: Number of Disciplines (across) versus Dollars per Drawing (down)

AD-A146 958 COST MODEL FORMULATION FOR ESTIMATING ARCHITECT - ENGINEER FEES AT BASE-L..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. J T RYBURN 2/2

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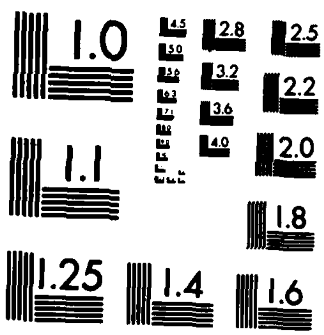
END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2.8
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2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

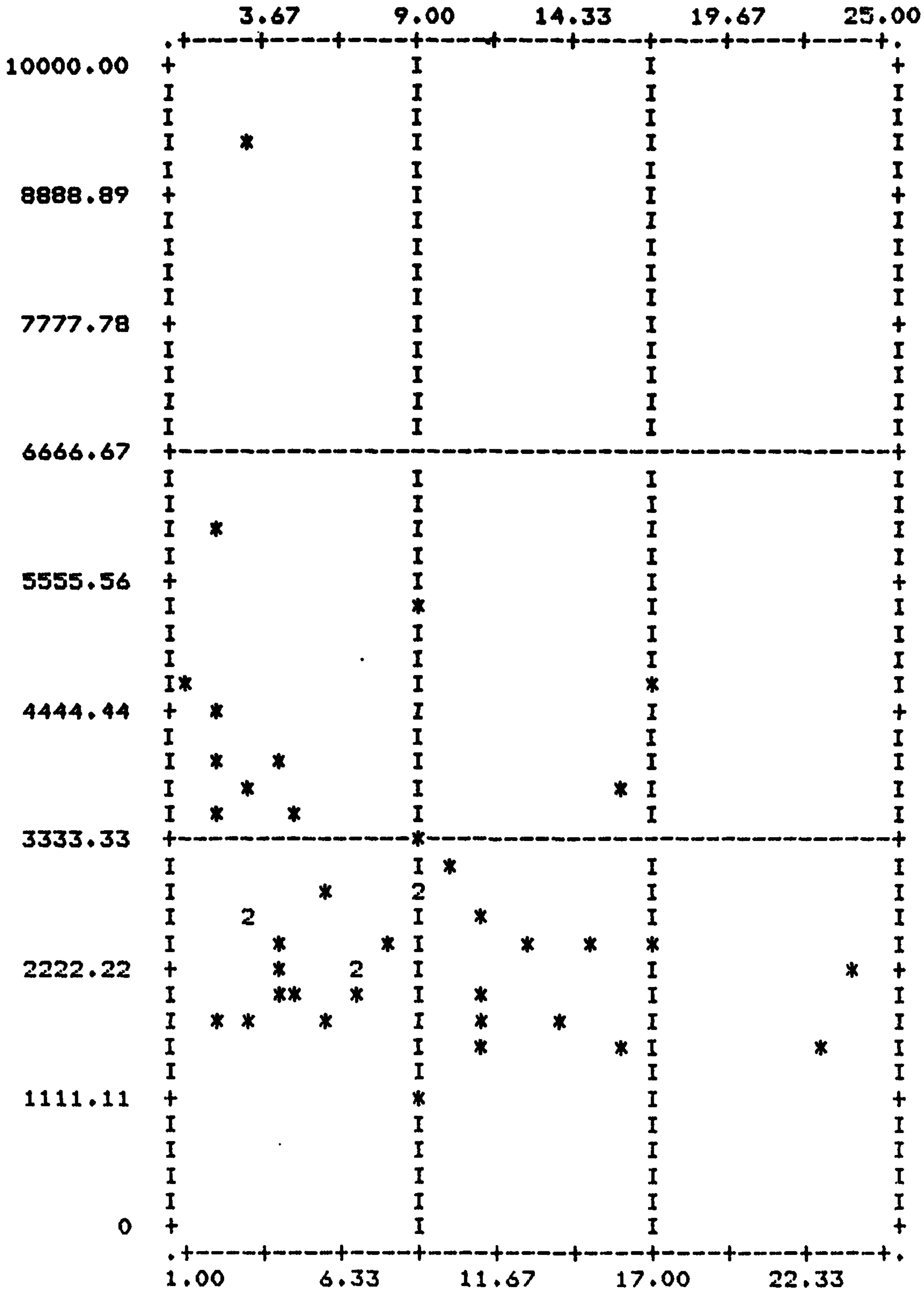

Figure 6. SCATTERGRAM Plot: Total Drawings (across) versus Dollars per Drawing (down)

TABLE XV

ANOVA Table: Fee as a Percentage of Estimated Construction Cost versus Number of Disciplines

VARIABLE PERC — FEE AS A PERCENTAGE OF ECC
BY NUM — NUMBER OF DISCIPLINES

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB
BETWEEN GROUPS	3	.009	.003	1.537	.221
WITHIN GROUPS	37	.074	.002		
TOTAL	40	.083			

GROUP	COUNT	MEAN	STAND. DEV.	STAND. ERROR	MIN.	MAX.	95 PERCENT CONF INT FOR MEAN
GRP 1	13	.07	.02	.00	.04	.10	.06 TO .08
GRP 2	8	.09	.07	.02	.03	.23	.03 TO .14
GRP 3	17	.10	.05	.01	.05	.24	.08 TO .13
GRP 4	3	.10	.04	.02	.07	.15	.00 TO .20
TOTAL	41	.09			.03	.24	

TABLE XVI

T-TEST Table: Single Discipline versus Multidiscipline for Fee as a Percentage of Estimated Construction Cost

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
PERC FEE AS A PERCENTAGE OF ECC				
GROUP 1	13	.0671	.015	.004
GROUP 2	28	.0971	.052	.010

		POOLED VARIANCE ESTIMATE			SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
11.17	.000	-2.04	39	.048	-2.82	35.45	.008

TABLE XVII

ANOVA Table: Fee in Dollars per Drawing versus Lead Discipline

VARIABLE DRAW   FEE DOLLARS PER DRAWING
BY LEAD   LEAD DISCIPLINE CODE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB
BETWEEN GROUPS	3	4547986.565	1515995.522	.651	.587
WITHIN GROUPS	37	86176009.784	2329081.346		
TOTAL	40	90723996.349			

GROUP	COUNT	MEAN	STAND. DEV.	STAND. ERROR	MIN.	MAX.	95 PERCENT CONF INT FOR MEAN
GRP 1	19	2724.50	1054.75	241.98	1208.79	4695.04	2216.12 TO 3232.87
GRP 2	1	3958.20	0	0	3958.20	3958.20	3958.20 TO 3958.20
GRP 3	14	3393.82	2192.25	585.90	1649.83	9424.80	2128.05 TO 4659.59
GRP 4	7	2933.54	782.48	295.75	2156.28	4411.12	2209.87 TO 3657.21
TOTAL	41	3018.83			1208.79	9424.80	

TABLE XVIII

ANOVA Table: Fee as a Percentage of Estimated Construction Cost
Lead Discipline

VARIABLE PERC FEE AS A PERCENTAGE OF ECC
BY LEAD LEAD DISCIPLINE CODE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB
BETWEEN GROUPS	3	.003	.001	.505	.682
WITHIN GROUPS	37	.080	.002		
TOTAL	40	.083			

GROUP	COUNT	MEAN	STAND. DEV.	STAND. ERROR	MIN.	MAX.	95 PERCENT CONF INT FOR MEAN
GRP 1	19	.09	.05	.01	.04	.23	.07 TO .12
GRP 2	1	.05	0	0	.05	.05	.05 TO .05
GRP 3	14	.09	.05	.01	.03	.24	.06 TO .12
GRP 4	7	.07	.02	.01	.06	.11	.06 TO .09
TOTAL	41	.09			.03	.24	

Appendix H: REGRESSION Results

TABLE XIX

REGRESSION: Drawings by Discipline with A-E Fee

VARIABLE(S) ENTERED ON STEP 1

ARCH	NUMBER OF ARCHITECTURAL DRAWINGS
STCIV	NUMBER OF STRUCTURAL CIVIL DRAWINGS
MECH	NUMBER OF MECHANICAL DRAWINGS
ELEC	NUMBER OF ELECTRICAL DRAWINGS

MULTIPLE R	.8477	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.7186	REGRESSION	4.	.106E+11	.266E+10	24.263
STD DEV	10473.6732	RESIDUAL	38.	.417E+10	.110E+09	SIG. .000
ADJ R SQUARE	.6890	COEFF OF VARIABILITY		44.9PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
ARCH	2159.520	437.857	24.325	.000	.45874	.35284
STCIV	5670.871	2123.262	7.133	.011	.24241	.07345
MECH	2296.265	781.078	8.643	.006	.32699	.28367
ELEC	2999.121	1240.794	5.842	.021	.27898	.22409
CONSTANT	1539.411	2732.974	.317	.577		

STEP	VARIABLE	E/R	F	MULT-R	R-SQ	CHANGE	R	OVERALL F	SIG.
1	ARCH	E	24.325	.628	.394	.394	.628	24.263	.000
	STCIV	E	7.133	.680	.462	.068	.211		
	MECH	E	8.643	.822	.675	.213	.642		
	ELEC	E	5.842	.848	.719	.043	.608		

TABLE XX

REGRESSION: Structural/Civil Discipline Removed from Model in Table XIX

```
DEP. VAR... IFEE        A-E FEE 84 DOLLARS

MEAN RESPONSE    22427.21250      STD. DEV.   19272.81382

VARIABLE(S) ENTERED ON STEP   1
ARCH        NUMBER OF ARCHITECTURAL DRAWINGS
MECH        NUMBER OF MECHANICAL DRAWINGS
ELEC        NUMBER OF ELECTRICAL DRAWINGS

MULTIPLE R     .8509 ANOVA          DF  SUM SQUARES  MEAN SQ.      F
R SQUARE       .7240 REGRESSION     3.    .941E+10  .314E+10    27.987
STD DEV  10588.2048 RESIDUAL       32.    .359E+10  .112E+09 SIG. .000
ADJ R SQUARE  .6982 COEFF OF VARIABILITY    47.2PCT

VARIABLE        B        S.E. B        F      SIG.       BETA   ELASTICITY

ARCH        2367.064   482.929    24.024  .000        .48401    .41045
MECH        2134.520   866.032     6.075  .019        .30049    .26702
ELEC        3306.423  1308.760     6.383  .017        .31719    .26619
CONSTANT    1263.518  2920.939      .187  .668

STEP VARIABLE E/R       F    MULT-R R-SQ CHANGE   R   OVERALL F  SIG.

 1   ARCH      E     24.024  .665  .443  .443  .665    27.987  .000
     MECH      E      6.075  .810  .669  .226  .625
     ELEC      E      6.383  .851  .724  .055  .675
```

TABLE XXI

REGRESSION: Total Drawings with A-E Fee

```
DEP. VAR... IFEE        A-E FEE 84 DOLLARS

MEAN RESPONSE     23260.05927       STD. DEV.    19114.12072

VARIABLE(S) ENTERED ON STEP    1
TOT          TOTAL NUMBER OF DRAWINGS

MULTIPLE R     .8576 ANOVA          DF   SUM SQUARES  MEAN SQ.      F
R SQUARE       .7355 REGRESSION      1.     .107E+11  .107E+11   108.450
STD DEV    9955.4801 RESIDUAL       39.     .387E+10  .991E+08 SIG.     0
ADJ R SQUARE   .7287 COEFF OF VARIABILITY    42.8PCT

VARIABLE         B       S.E. B        F      SIG.       BETA   ELASTICITY

TOT        2608.163   250.450   108.450     0       .85761     .94627
CONSTANT   1249.712  2623.823      .227  .637
```

TABLE XXII

REGRESSION: Total Drawings and Estimated Construction Cost with A-E Fee

VARIABLE(S) ENTERED ON STEP 2
IECC ESTIMATED CONSTRUCTION COST 84 DOLLARS

MULTIPLE R	.9333	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.8710	REGRESSION	2.	.127E+11	.636E+10	128.338
STD DEV	7042.2682	RESIDUAL	38.	.188E+10	.496E+08	SIG. .000
ADJ R SQUARE	.8643	COEFF OF VARIABILITY		30.3PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
TOT	2002.794	201.400	98.891	.000	.65856	.72664
IECC	23.705	3.751	39.941	.000	.41853	.31930
CONSTANT	-1068.550	1891.931	.319	.576		

TABLE XXIII

REGRESSION: Total Drawings, Estimated Construction Cost, and Community Facility with A-E Fee

VARIABLE(S) ENTERED ON STEP 3
COM COMMUNITY OR NOT COMMUNITY

MULTIPLE R	.9346	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.8735	REGRESSION	3.	.128E+11	.426E+10	85.156
STD DEV	7068.7911	RESIDUAL	37.	.185E+10	.500E+08	SIG. 0
ADJ R SQUARE	.8632	COEFF OF VARIABILITY		30.4PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
TOT	1900.098	235.819	64.922	0	.62479	.68938
IECC	24.052	3.787	40.332	0	.42465	.32398
COM	2573.692	3042.915	.715	.403	.05854	.02699
CONSTANT	-938.328	1905.288	.243	.625		

Appendix I. Using the Cost Models

Some of the percentages and breakdown figures outlined below are hypothetical and not based on analysis of this data base but on the experience of the author.

Grand Total Fee. The Grand Total Fee (GTF) for projects within the range of this data base can be estimated with the formula:

```
GTF = 2002.79 * (TOT. DRAWINGS) +
     .0237 * (ECC 1984 DOLLARS) -
      1068.55
```

This formula gives the fee in 1984 dollars, which must be adjusted with appropriate index numbers for other year estimates. The Total Fee also includes both Title Ia and Ib services. With good estimates of the total number of drawings and estimated construction cost it is possible to reach a fair estimate for total fee. In order to develop a detailed estimate, it is necessary to work backwards toward a fee breakdown.

Before breakdown, adjustments to the Grand Total Fee can be made for certain project characteristics such as shown in Table VIII on page 56.

Comparisons can be made with some of the simpler models to get a subjective appraisal of the fee range based on the special characteristics of the project, and the Grand Total Fee adjusted accordingly.

Breaking Down the Fee. After an adjusted Grand Total Fee is derived, it must be reduced to its components. Two values are required for the initial breakdown:

P = percentage of profit

OH = percentage of overhead

Typical values are 10 percent for profit and 120 percent for overhead. To reach a direct labor (DL) price, it is necessary to subtract overhead and profit from the total fee.

$$GTF*(1.0 - P)/(1.0 + OH) = DL\ DOLLARS$$

Once direct labor dollars are derived, it is necessary to divide the fee into Title Ia and Ib proportions. In the author's experience, the Title Ib services nearly always reach the maximum six percent of estimated construction cost for small maintenance and repair and alteration jobs. This is generally a good departure point. A typical proportion might be 70% for Title Ib and 30% for Title Ia. Direct labor dollars is then divided proportionately for Title Ia and Ib services and checked against the six percent limitation.

Title Ib must then be divided into direct design dollars and design support dollars. Design support includes cost estimators, specification writers, and their technicians. Direct design includes the design disciplines and their drafting support. A typical proportion for direct design and design support would be 80 percent direct design and 20 percent design support.

Direct Design can then be broken down by discipline. A quick way to work backwards is to divide the direct design by total number of drawings, then, with a good knowledge of local labor rates, it is possible to proportion the hours by discipline.

Another way to work forward on Title Ib services is to strip the Cost per drawing for the data base by subtracting profit, overhead, Title Ia, and design support percentages. Using the $2964 per drawing cost and the percentages already discussed, a dollars per drawing of $1244 is reached. This figure can be used to proportion direct design dollars.

Title Ia services can be broken down as required for sub-surface investigations, topographic surveys, field investigation, and reproduction costs. These are all project unique requirements, except reproduction, which can be easily determined with the estimated number of drawings and experience in reproduction cost.

This backwards breakdown can provide most of the elements required to produce a good detailed cost analysis. Certain figures derived in this manner will require some subjective manipulation to make the estimate reasonable for some unique requirements. However, the cost model can be a useful tool in providing a point of departure for developing detailed estimates.

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Captain James T. Ryburn was born 4 June 1951 in Little Rock, Arkansas. He graduated from high school in Benton, Arkansas, in 1969 and attended the University of Arkansas from which he recieved the degree of Bachelor of Architecture in 1975. He recieved his commission in 1975 from Officer Training School and was first assigned as a Civil Engineering Officer at Shaw AFB, South Carolina. In 1978, he was assigned to the 554th Civil Engineering Squadron (Heavy Repair) where he served as Commander, RED HORSE Operating Location at Taegu, Korea. In 1979 he was selected to attend the Education With Industry program under Air Force Institute of Technology sponsorship. He was assigned to Daniel, Mann, Johnson, and Mendenhall, an architecture engineering firm in Los Angeles, California. In 1980 he was reassigned to Bitburg AB, Germany where he served as Base Architect, Chief of Design, and Deputy Base Civil Engineer. In 1981, Captain Ryburn was selected as Civil Engineering Inspector, USAFE Inspector General, Ramstein AB, Germany where he served until selected for the Graduate Engineering Management program, Air Force Institute of Technology, in 1983. Upon graduation from AFIT, Captain Ryburn will be assigned as Chief of Operations, 823rd Civil Engineering Squadron (Heavy Repair) at Hurlburt Field, Florida. He is a registered architect with the state of Minnesota.

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Title: COST MODEL FORMULATION FOR ESTIMATING ARCHITECT - ENGINEER FEES AT BASE-LEVEL CIVIL ENGINEERING

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The purpose of this ~~research~~ thesis was to statistically analyze a base-level data base of Architect-Engineer (A-E) contracts to demonstrate the possibility of cost model formulation to predict or estimate A-E fees. The models were based on the "cartooning" estimating technique for developing fee estimates based on the expected number of drawings required in the final A-E design. The data base was the A-E contracting activity of the 2750th Civil Engineering Squadron at Wright-Patterson AFB, Ohio, and included 44 contracts from a five year period. Analysis of variance was used to separate project characteristics which affected the per drawing cost. Utility work, number of disciplines, community facilities, and total number of drawings affected the per drawing cost. Simple and multiple linear regression were used to derive cost models for predicting A-E fees on future projects. Four cost models were developed. Only one cost model using number of drawings was judged successful based on the statistical criteria. However the technique of cost model formulation for estimating A-E fees was demonstrated.

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